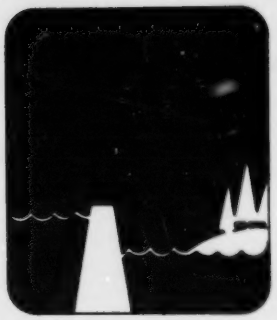
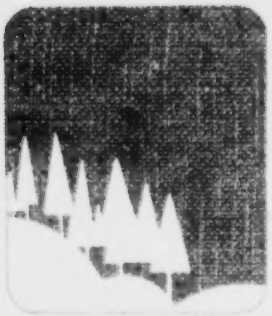
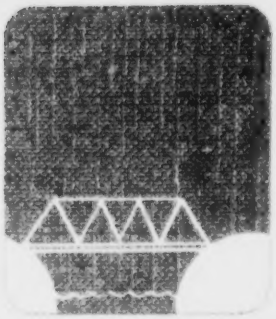
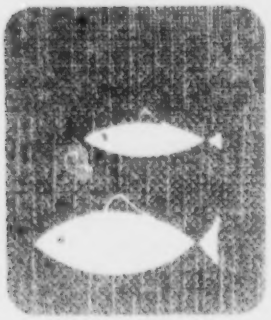

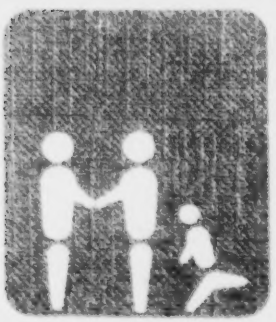

lake winnipeg, churchill & nelson rivers study board CANADA MANITOBA 1971-75

hydrologic, hydraulic & geomorphologic studies

vol 1 technical report appendix **2**

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

APPENDIX 2 - HYDROLOGIC, HYDRAULIC AND GEOMORPHOLOGIC STUDIES, VOL. 1

A - PHYSICAL IMPACT STUDY

B - LAKE WINNIPEG SHORELINE EROSION, SAND MOVEMENT AND ICE EFFECTS STUDY

C - ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE AND 2-MILE CHANNELS

D - REVIEW OF ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE CHANNEL

E - ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION FOR THE SOUTH BAY - ISSETT LAKE DIVERSION CHANNEL

F - ANTICIPATED EFFECTS OF THE CHURCHILL RIVER DIVERSION PROJECT ON THE ICE COVER OF SOUTHERN INDIAN LAKE

G - POST-DIVERSION ICE REGIME STUDY OF THE LOWER CHURCHILL RIVER

H - EAST CHANNEL HYDRAULIC STUDY

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

PHYSICAL IMPACT STUDY

PREPARED BY:
GEOTECHNICAL SECTION
PLANNING DIVISION
WATER RESOURCES BRANCH
DEPT. OF M. R. AND E. M.
PROVINCE OF MANITOBA

JULY, 1974
WINNIPEG, MANITOBA

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

ACKNOWLEDGMENTS

The first phase of this study was conducted under the direction of Dr. R. W. Newbury of the Department of Civil Engineering, University of Manitoba and was reported in a document entitled "Physical Impact Study, Interim Report 1972." The Interim Report contained the Shoreline Classification System and the classification of the natural state shorelines on the Upper and Lower Nelson Rivers, the Lower Churchill River and of the Rat-Burntwood River System. These sections have been incorporated into the present report with only minor changes.

On April 1, 1974, the study was taken over by the Water Resources Branch and completed by staff under the direction of Mr. Frank Penner.

ABSTRACT

The Physical Impact Study deals with the physical impact on shorelines and inundated terrain resulting from the interbasin transfer of water from Churchill River to the Nelson River and the regulation of flow in the Nelson River by Jenpeg. These waters are to be diverted and regulated for the purpose of hydroelectric development.

The study area has been broken down into stretches of waterways. Along the Upper Churchill River, Leaf Rapids to Missi Falls, water levels will be raised thereby affecting a portion of the Churchill River, Opachuanau Lake and Southern Indian Lake. Waters which normally flow down the Lower Churchill River, Missi Falls to Hudson Bay, will be redirected to flow via South Bay on Southern Indian Lake into the Rat-Burntwood Rivers and adjoining lakes. Diverted waters will be regulated by the Notigi control structure and supplement the Nelson River flows which join the Burntwood River at Split Lake. The Lower Nelson River flows from Split Lake to Hudson Bay. Nelson River waters flowing into Split Lake from Lake Winnipeg (Upper Nelson River) are regulated by the control structure at Jenpeg.

Shoreline and inundated terrain classification systems were developed in order to describe the shorelines and terrain to be affected. General impact process statements define the impact expected to occur to the shorelines and terrain under various flooding levels for specific periods of time. Natural process statements describe the natural development of the shorelines and the terrain. Site specific natural state conditions and impacted state conditions are discussed for the lakes and channels. Water level and flow data is included for each waterway.

The addendum deals with the physical effects of the proposed hydro generating stations along the Burntwood River. These reservoirs would be formed at Wuskwatim Lake, Manasan Falls and First Rapids.

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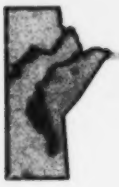


1.0 RECOMMENDATIONS

1.1 INTRODUCTION

The Physical Impact Study was designed chiefly to provide input to other associated studies. Hence, recommendations for enhancement of benefits and mitigation of damages are limited.

The great size of the Study Area and limited time available permitted the preparation of generally qualitative, and in some cases tentative impact process statements. Moreover, the specific questions requiring answers emerged and were clarified only gradually during the course of the study as a result of interaction between staff of various disciplines.

At this time, there are several specific studies which ought to be pursued further to determine whether and what type of remedial action ought to be undertaken. These are described below.

1.2 THE SHORELINE EROSION PROCESS

The shoreline process associated with raised water levels results in:

1. Loss of land
2. Generation of sediment and turbidity

Loss of land is generally detrimental since it is a loss of a resource and requires relocation of structures. However, erosion of overburden from low islands creates reefs useful as habitat for certain bird species. Similarly, under appropriate conditions the erosion process may produce sand beaches or expose gravel beds suitable as fish spawning grounds. Erosion has the effect of re-establishing the pre-flooding type of shoreline at a higher elevation. The harmful effects of erosion are generally limited to this adjustment phase. There is very little date available on the rate of erosion and duration of the adjustment phase for various conditions. Such information is necessary for assessing the impact of erosion and in determining the need for or type of remedial works required. Hence, it is recommended that rates of erosion and adjustment be monitored under various conditions - both lakes and rivers - for an extended period of time - say 10 years.

Sediment generated by the erosion process may have the harmful effect of silting over gravel substrate suitable for fish spawning areas. It would be helpful to know how far or to what depth the sediment is carried before it is deposited under various conditions. Hence, it is recommended that the transport and deposition of sediment opposite several eroding banks be monitored for an extended period of time - say 10 years.

Suspended sediment and turbidity affect water quality and have related effects on water treatment requirements and aquatic ecosystems. Suspended sediment observations on rivers with clay shorelines also provide useful measures of the amount of channel erosion. It is recommended that a program of water quality monitoring be established on the Burntwood River.

1.3 FLOODED FOREST

Most of the land to be flooded is forested. At the present time, the cost of harvesting the timber generally exceeds the value of the timber salvaged (Reference 1). The high cost of cutting, piling and burning the trees

generally precludes clearing the total area to be flooded. Hence, some forest is left standing while in some other areas trees are slashed - cut and left lying in place. At this time, the relative merits of complete clearing, slashing only and leaving flooded forests standing are not sufficiently clear to permit satisfactory definition of areas to be completely cleared or slashed. In particular, the merits of slashing compared to leaving trees standing are not clear in so far as the problem of floating debris is concerned. Considerable uncertainty exists as to whether slashed timber will submerge in place or will float. Hence, it is recommended that systematic observations be made of the flooded treed areas which have been treated in different ways. These observations should also include data on the effectiveness and costs of post-flooding reservoir management.

2.0 OBJECTIVES

The objective of this study was to determine the physical characteristics of lakes and channels in the Churchill River and Nelson River systems in Manitoba and determine the shift in characteristics due to the imposition of engineering works for the diversion of the Churchill River and the regulation of Lake Winnipeg.

The results of this study were to serve as basic inputs to associated studies in physically related fields including recreational use, wildlife use, fisheries, habitation potential and transportation.

3.0 TERMS OF REFERENCE

The Canada-Manitoba Study Agreement for Lake Winnipeg and the Churchill and Nelson Rivers provides for studies to determine the effects that regulation of Lake Winnipeg, diversion from the Churchill River and development of hydro-electric potential of the Churchill River diversion route are likely to have on other water and related resource uses and to make recommendations for enhancing the overall benefits with due consideration for the protection of the environment. These studies are to be sufficiently broad to provide reliable data on present natural conditions and the anticipated and actual conditions arising from the operation of the controls and diversion as designated and constructed. One component of the study, "Erosion and Sedimentation", requires an estimate of changes in channel and bank morphology of both donor and receiving streams below points of diversion, and in shoreline erosion and sediment movement patterns in the larger lakes affected by regulation. The Physical Impact Study was designed to provide this information in broad outline for the total Study Area except for Lake Winnipeg which was covered by another more detailed study (Reference 2).

Certain information was taken as given, namely that Lake Winnipeg would be regulated between the levels of 711 and 715 feet elevation and that Southern Indian Lake would be raised to not more than 850 feet elevation for a diversion out of the Churchill River of up to 30,000 cfs.

The effects of hydro-electric developments, on the Burntwood River at Wuskwatim, Manasan and First Rapids will be the subject of an addendum to this report.

The study of the Lower Nelson (below Kettle Rapids) was limited to the effects of increased flows due to regulation of Lake Winnipeg and diversion of the Churchill River. The effects of proposed hydro-electric developments below Kettle Rapids were not within the terms of reference of this study.

4.0 STUDY AREA

4.1 LOCATION

The study area is within the boundaries of latitudes 50° 30' and 59° 00' north, and the longitudes 92° 30' and 100° 00' west. The study area includes Lake Winnipeg and the major portions of the Churchill River and Nelson River Systems in the north-central portion of Manitoba, Canada, (Figure 1).

Much of the description of the study area was taken from Reference 1 with minor deletions and additions being made. Five geographical divisions or areas for studies were determined on the basis of (a) the location of Hydro's proposed developments, and (b) environmental impacts associated with these developments. The changing water regimes as they occur in these locations are briefly discussed under the five area sub-headings below. Detailed information on each area is provided under appropriate sections on natural state and environmental impact.

- AREA I - LAKE WINNIPEG: The outlet capacity of Lake Winnipeg will be increased and a control structure will be installed at Jenpeg on the West Channel of the Nelson River to regulate the lake. The regulation will alter the pattern of Lake Winnipeg levels from those occuring naturally.

  The effect of the regulation of the level of Lake Winnipeg on the shoreline is the subject of a separate study (Reference 2) and will not be considered in this report.

- AREA II - OUTLET LAKES AND THE NELSON RIVER: The pattern of levels and flows will be altered in the lakes and the Nelson River channels above and below the Jenpeg control structure. Specific waters of concern in the Outlet Lakes area include the East and West Channels of the Nelson River, Kiskitto Lake, Kiskittogisu Lake, Playgreen Lake, Pipestone Lake and Cross Lake. Locations of Manitoba Hydro's control works in the Nelson River and Outlet Lakes areas are shown on Figure 1.

- AREA III - DIVERSION ROUTE: Diversion of the Churchill River will introduce additional water to the Rat and Burntwood rivers. This will greatly increase flows in these streams and alter the water levels in the stream channels. The flow patterns, water level fluctuations and water quality will also be significantly changed in these rivers. In addition, proposed hydro-electric power projects along the diversion route will flood land and form new shorelines in reservoir areas (Figures 2 and 3).

- AREA IV - SOUTHERN INDIAN LAKE: Lake levels at Southern Indian Lake will increase by approximately ten feet to an elevation of 847 feet following completion of the Missi Falls and Notigi control works. Raised water levels will increase the area of Southern Indian Lake by 13% to about 790,000 acres (Reference 3).

- AREA V - LOWER CHURCHILL RIVER: Diversion of 30,000 c.f.s. out of Southern Indian Lake will significantly alter the quantity and pattern of flow in the Churchill River downstream from Missi Falls to Hudson Bay, and, consequently, the pattern of water level fluctuation (Figure 4).

4.2 GEOGRAPHY

The geography of the study area considers the surface of the earth, including its form and development, the phenomena that take place thereon, and the plants, animals and peoples that inhabit it, considered in relation to the earth's surface.

- PHYSICAL FEATURES: Area 1, Lake Winnipeg, is discussed in Reference 2 and is not included here. Area II above Kettle, Area III and Area IV are charaterized by rolling undulating topography of low relief that forms part of the Precambrian Shield. The numerous lakes, swamps and bogs are joined by meandering streams (Photograph 1). Area II downstream from Kettle and Area V have more and often broad depressions. Stretches of both the Churchill and Nelson Rivers have steep banks that gradually decrease in slope as they approach the estuaries of the rivers at Hudson Bay.

Granite is the dominant bedrock, but gneissic rocks occur in wide belts. Volcanic and metamorphosed rocks appear locally. A thin mantle of glacial till was deposited by melting ice as ground moraine. This till is often a loamy sand composed of Precambrian rock fragments. In some locations a loamy clay of calcareous till resulted from a re-advance of the glaciers over lacustrine sediments. Till was locally concentrated in streamlined hills or drumlins, but the relief of the ground moraine is largely determined by bedrock. Esker deposits of sand and gravel (Photograph 2) were laid down by rivers flowing under glacial ice. These now form meandering sandy ridges of considerable relief (Reference 4).

Fine textured lacustrine clay deposits of Lake Agassiz covers a major portion of the study area. In Reference 4, the main vegetative area was divided into three zones which are discussed more fully under the following subsection on vegetation and are shown in Figure 5. Permafrost is widespread in clays of all classes in the north zone and on some poorly drained clays in the mid zone. Clays in the south zone are generally free of permafrost. Most mineral as well as organic soils in the north zone contain permafrost, whereas, the permafrost in the south zone (Figure 5) is confined mainly to the organic soils. The mineral soils - Lurisolic, Brunisolic and Gleysolic are described in Reference 5. Organic soils are accumulations of organic residues which are saturated for most of the year. They consist mainly of three kinds of organic material: forest peat, sphagnum moss peat and herbaceous peat (Reference 6).

Soils having a hummocky micro-relief with permafrost are characterized by domed conditions and the presence of fibrous sphagnum peat or moderately decomposed forest peat. Such domes or palsas (Reference 7) may be elevated more than ten feet. They develop when accumulating peat and living vegetation provide sufficient insulation for the frozen layer to increase in volume. As the thickness of the frozen layer increases, an unstable situation arises: the surface moss layer cracks and the sides slump. This partial destruction of the insulative cover changes the energy balance causing the frozen layer to melt with concurrent collapse of the palsa.

- VEGETATION: The study area is located in the Northern, or Boreal Forest Region. Black spruce, Picea mariana (Photograph 3), is in general the dominant tree specie. Habitat or site conditions often change rapidly over relatively short distances and is an important basis for determination of forest communities. In Reference 4, the area was divided into three zones: (1) South Zone; (2) Mid Zone; and (3) North Zone (Figure 5). In Reference 4, each zone is characterized by a number of key species and the following conditions:

North Zone

a. Open black spruce forests with a ground vegetation of lichen and low prostrate shrubs and with a discontinuous stratum of medium shrubs occurs on moist to fresh sites.
b. White spruce forests on favourable and dry sites (flood plains and eskers); jack pine forest occurs on dry sites only in the southern parts.
c. Muskeg (black spruce) and bog vegetation occurs on saturated sites (Photograph 4).
d. Tamarack, Larix laricina, is the most important tree of subseral communities on moist to fresh sites, forming stands in association with willows, Salix spp., alder, Alnus spp. and black spruce, Picea mariana.

Mid Zone

a. Closed black spruce forests (Photograph 3) with a continuous ground cover of mosses but lacking other tree or tall shrub stratum occur on moist to fresh sites.
b. White spurce, Picea glauca, occurrence is sporadic and limited to the more favourable sites (side hill clays).
c. Muskeg (black spruce) and bog vegetation occurs on saturated sites (Photograph 4).
d. Jack pine, Pinus banksiana, forests occur on dry sites.
e. A seral type sequence occurs on moist to fresh sites of swamp birch, Betula glandulosum, willow, Salix spp. open pine forest and white spruce, Picea glauca, white birch, Betula Papyrifera, and closed black spruce forest, Picea mariana.

South Zone

a. Mixed white spruce and trembling aspen forests occur on moist to fresh sites.
b. Muskeg (black spruce, tamarack and locally eastern white cedar) and swamp and meadow vegetation occur on saturated sites.
c. Jack pine, aspen or in the southern parts - bur oak Quercus macrocarpa occur on dry sites.
d. Aspen and jack pine are important trees in subseral communities.

Key species for each zone are listed in tabular form in Reference 5.

Abrupt changes in the environment are brought about by fires and lumbering. These have a significant effect on the vegetation of the area. Photograph 5 shows the mass of fireweed, Epilobium angustifolium, that gives a pinkish hue to the burned-over landscape. This is often the first stage of vegetative succession. Generally speaking, jack pine colonizes burnt over areas and hardwood species follow lumbering. Moisture and soil conditions are the major factors determining species distribution. Black spruce is the climax forest where the environment is suitable.

4.3 CLIMATE

The climate of the study area is continental and is characterized by short, cool summers and long, cold winters. In relation to world wide climatic conditions, the area is within the cool snow-forest climates. These entail fairly dry winters. The mean monthly temperatures have the greatest range between January and July, and the greatest range of about 80° F occurs at Brochet. The other recording stations - Wabowden, Thompson, Norway House, Gillam and Flin Flon have a mean range between 70 and 75° F. All recording stations have a mean annual temperature of less than 32° F, ranging from 22.7° F to 31.3° F. The mean monthly precipitation for the stations is highest in the month of July. The annual precipitation varies from 16 to 18 inches. About two-thirds of the yearly precipitation falls during the summer months (May to the end of September). On the average, less than one inch of precipitation occurs in each of the winter months. Tables of mean monthly and annual temperatures and precipitation for the reporting stations for the year 1941 - 1970 are presented in Reference 5.

4.4 PEOPLE

Thompson, incorporated as Manitoba's newest city in July, 1970, is located 400 miles north of Winnipeg (Reference 8). The estimated population is 20,000. Rail service is supplied by Canadian National Railways (Figure 6). Road access is provided by Provincial Route #391 , (Figure 2) and by Provincial Trunk Highways (P.T.H.'s) #6 and #10. The economy and existence of the city is mainly dependent on the operation of International Nickel Co. Ltd., which started in 1956-57. The city is emerging as the administration and regional centre for Northern Manitoba.

Churchill is situated at the mouth of the Churchill River on the shore of Hudson Bay, 1,000 miles by rail north of Winnipeg (Figure 6). Churchill's population is approximately 3,200 (Reference 8). It is Canada's most northerly deep sea port through which millions of bushels of grain are shipped each year. The Churchill route to the European market is about 1,000 miles shorter than that through Montreal and investigations are underway to see if the 3½ month shipping season can be extended. Churchill is the northern area headquarters for a number of Federal Government departments and agencies which employ approximately 500 persons.

Gillam (Figure 6) is 455 air miles north of Winnipeg. The population is approximately 3,000 (Reference 9). The town was a divisional point on the Hudson's Bay Railway, having a sizeable contingent of railway employees. With the start of the Kettle Dam and generating station on the Nelson River about five miles from Gillam, the population expanded rapidly. The first

generating unit at Kettle Rapids (Figure 6) went into operation in 1970 (Reference 9).

Ponton (50)[1], Thicket Portage (320)[1] and Ilford (230)[1] are situated along the Hudson's Bay Railway (Figure 6). These villages, particularly Wabowden, act as supply points for tourists, local inhabitants, and business personnel. All except Ilford have access by P.R. #391, P.T.H.'s #10 and #6.

[1]*Approximate populations according to Reference 8.*

Norway House (2,000)[2], Nelson House (1,300)[2], South Indian Lake (590)[2] and Warren Landing (30)[2] are all native communities. Cross Lake and Nelson House are registered as primarily Indian Communities, while Norway House, South Indian Lake, and Warren Landing are mixed Indian-Metis communities. Families are generally large and a high proportion of the population is under the age of 15 years. The incidence of unemployment is high among both males and females, but especially in the latter case, where rates of unemployment of 80 to 90 per cent are not uncommon. Large percentages of the labour force are engaged in seasonal activities such as fishing, trapping and to a lesser extent, lumbering. In general, the problems of the communities are characterized by low incomes, high food prices and lack of adequate housing, (Reference 9).

[2]*Approximate populations according to Reference 9.*

4.5 PROPOSED WORKS

Manitoba Hydro has developed plans for a multi-billion dollar development of the hydro-electric potential of the Churchill and Nelson Rivers in Northern Manitoba. The power production capacity is of similar order of magnitude as the La Grande hydroelectric development proposed for the James Bay area, Quebec, and the recently completed Churchill Falls hydroelectric development, Labrador (Reference 3). The completed development would constitute 14 power stations. These power stations, the year of their proposed operation and the power developed by each are shown in Figure 3; the location of each is shown in Figure 4. Except for the Notigi and and Jenpeg reservoirs, the present study does not include the impact on shorelines by construction of the power stations.

4.5.1 THE NELSON RIVER HYDROELECTRIC DEVELOPMENT - Manitoba Hydro's proposed sequence for power development involves, respectively, Regulation of Lake Winnipeg and Diversion of the Churchill River from Southern Indian Lake to the Nelson River (Figure 4). The Churchill River will be diverted by a control dam at Missi Falls (Figure 4) at the outlet of Southern Indian Lake. Water will be diverted from South Bay at Southern Indian Lake through a diversion channel to Issett Lake, the headwaters of Rat River. A control structure at the outlet of Notigi Lake on the Rat River will regulate the release of water down the Burntwood River and onward to the Nelson River (Figure 4).

LAKE WINNIPEG REGULATION: Lake Winnipeg will be regulated by improved outlet capacity at the north end of the lake and a control and power generating facility on the West Channel of the Nelson River at Jenpeg (Figure 7). Lake Winnipeg is the largest Manitoba lake having a surface area of 9,430 square miles. It ranks as the twelfth largest lake in the world draining a 380,000 square mile watershed extending to the Canadian Rockies. Waters flow out of the north end of Lake Winnipeg to the Nelson River via the West and East channels.

The major portion of the flow from Lake Winnipeg moves through the West Channel via Playgreen Lake and Kisipachewuk, Metchanais and Ominawin rapids to Cross Lake. The remainder of the Nelson River flow enters Cross Lake via Little Playgreen Lake and the East Channel (Figure 7).

Lake Winnipeg is particularly suited for hydroelectric purposes because of its large storage. By increasing the outlet capacity and regulating flows from Lake Winnipeg, winter flows in the Nelson River required for power generation can be increased to coincide with peak annual energy demands.

Flood control benefits for lands bordering the lake may also accrue to the project.

In order that waters may be stored and released for power generation, Lake Winnipeg will be regulated between 711 and 715 feet by a control dam and generating facility on the West Channel of the Nelson River and by-pass channels at the north end of the lake. Further, a lesser system of dams and dykes will be constructed in the project area to increase hydraulic control and restrict flooding (Figure 7).

WEST CHANNEL CONTROL AND GENERATING FACILITIES: The regulating structure and generating station constructed at Jenpeg on the West Channel of the Nelson River (Figure 7) will control approximately 75% of the average Lake Winnipeg outflow (72,500 cfs.). The Jenpeg generating station will generate 168,000 kw by using a head of approximately 25 feet, creating an impoundment of an undetermined surface area but relatively restricted to the immediate area of the West Channel. Average annual flows through the six turbines at Jenpeg will be slightly less than the average unregulated flows in this part of the West Channel. A clearing program to partially clear the Jenpeg forebay area has begun and will be completed before impoundment begins in 1974. Dyking has been designed to restrict flooding in some areas as a result of increased water levels in the West Channel. Power production at this site is expected for 1976.

OUTLET CHANNELS: Three (3) channels referred to as the 8 Mile Channel, 2 Mile Channel and Ominawin By-pass Channel, are being excavated to increase the outflow capacity of the lake. Limited channel improvement has been completed at Kisipachewuk Rapids (Figure 7).

The 2 Mile Channel approximately 425 feet wide and 25 feet in depth below water level will be excavated by a hydraulic suction dredge and conventional means to improve discharge capacity between Lake Winnipeg and Playgreen Lake (Figure 7). Forest cover along the channel route has been cut, piled and will be burned. Approximately 12,800,000 cubic yards of primarily silty clay will be removed and deposited on either side of dykes bordering the channel. Mean velocity through the channel is estimated to be 2.0 feet per second which will allow a permanent winter ice cover. Dredging will commence on the 2 Mile Channel in early 1974 and the channel is expected to be completed and operational in the fall of 1975.

The 8 Mile Channel connecting Playgreen Lake to Kiskittogisu Lake is being

dredged to improve discharge capacity between these two lakes (Figure 7). The 8 Mile Channel will vary in width from 425 to 1,000 feet, accommodate a median velocity of 2.0 feet per second and will require the removal of approximately 22,100,000 cubic yards of primarily clay-peat material. Dyking on either side of the channel is designed to prevent dredge-spoil pumped onto the landscape from entering the channel. Dredging of the 8 Mile Channel commenced in early 1972 and the channel is expected to be completed by late 1974.

The Ominawin By-pass is a channel excavated to divert flows around the Ominawin Rapids to the West Channel (Figure 7). The Ominawin By-pass channel is approximately two miles long, 1,000 feet wide and 25 feet deep and will require excavation of 8,000,000 cubic yards of overburden and 650,000 cubic yards of rock by conventional means. Excavation should be completed in early 1974 and the channel operational in the latter part of 1974.

An estimated 10,000 cubic yards of rock has been excavated to increase flows through the Kisipachewuk outlet channel.

KISKITTO LAKE REGULATION: A system of lesser dams and dykes required for improved hydraulic control and to restrict flooding is associated with the West Channel Jenpeg control dam and the man-made channels. Kiskitto Lake will be controlled by a series of dams and dykes at the outlets from Kiskitto Lake to Black Duck Creek and the West Channel of the Nelson River (Figure 7). These structures will maintain the level of Kiskitto Lake independent of Lake Winnipeg and the fluctuations will not be the same as that of the other outlet lakes. The water flow through Kiskittogisu Lake passes through two channels into the West Channel of the Nelson River (Figure 7). Regulation will decrease the natural range of Kiskitto Lake level fluctuations from an historic natural range of 686.5 to 702.3 feet to elevations of 695.2 to 698.3 feet.

4.5.2 CHURCHILL RIVER DIVERSION - The works required for Churchill River diversion include construction of the Missi Falls control structure, South Bay diversion channel and Notigi control facilities (Figure 4).

MISSI FALLS CONTROL: A gated control structure and spillway at Missi Falls will be constructed by Manitoba Hydro to control the outflows from Southern Indian Lake to the Churchill River. Present water levels of Southern Indian Lake will be raised by approximately 10 feet to elevation 847 feet, the maximum elevation not to exceed 850 feet. A maximum drawdown or fluctuation of about 2 feet (845 - 847) is expected during any normal 12 month period. Historically, Southern Indian Lake levels have fluctuated from a minimum elevation of 834.0 feet to a maximum elevation of 842.8 feet maintaining an average long-term lake level elevation of about 836.5 feet.

With control, average outflows at Missi Falls will be reduced by approximately 75% to allow for average diversion flows of about 27,000 cfs. to the Nelson River. In the past, outflows from Southern Indian Lake have varied from about 20,500 cfs. to 92,000 cfs. with a long-term mean of about 36,000 cfs. Churchill River flows at Hudson Bay will be reduced by approximately two-thirds

of its historic average flow (40,900 cfs. to 14,100 cfs.).

Construction of the Missi Falls control structure is proceeding and impounding of water is expected to begin in 1974. Flooding to the full supply level (847 feet) is expected to be completed by late 1975.

SOUTH BAY DIVERSION CHANNEL: A diversion channel will be excavated from South Bay of Southern Indian Lake to Issett Lake on the head waters of the Rat River to divert up to 30,000 cfs. from the Churchill to the Nelson River (Figure 4). The channel will be approximately 5½ miles long and maintain an average width of about 850 feet. Approximately one mile from Issett Lake, the channel widens to 2,500 feet. The depth of the channel varies from 23 to 32 feet to accomodate average flows at less than 2 feet per second velocity.

The channel route has been cleared of timber and excavation contracts have been awarded by Manitoba Hydro.

NOTIGI CONTROL: A control structure will be constructed at the south end of Notigi Lake to regulate upstream water levels. The Notigi control will release a maximum of 30,000 cfs. to the Burntwood River. Manitoba Hydro intends to use the natural inflow from the Rat River Basin to raise water levels in the Notigi forebay from 790 to 832 feet by September, 1975. Further increased water levels to 847 elevation will be achieved by diverting waters from the Churchill River via the South Bay Channel beginning November, 1975.

Historically, the Rat River at Notigi Lake has had an average annual flow of about 1,100 cfs.. With the Notigi Lake control, the Rat River will become part of an impoundment resulting from flooding of approximately 226 square miles. The Notigi Lake control will maintain a head from 30 to 40 feet. The drop in water level from South Bay to Notigi may vary from two feet under open water conditions to nine feet under ice conditions. The minimum water level for the Notigi forebay area is defined by terms of license as 838 feet. Releases through the Notigi control will be such as to restrict maximum flows in the Burntwood River (at Thompson) to 34,000 cfs. (the combined average historical mean flow of 4,000 cfs. and diversion flows of 30,000 cfs.).

4.5.3 BURNTWOOD RIVER GENERATING STATIONS - WUSKWATIM, MANASAN AND FIRST RAPIDS GENERATING STATIONS: Three generating stations identified as Wuskwatim, Manasan and First Rapids having a combined capacity of approximately 640,000 kw have been proposed by Manitoba Hydro for development along the Burntwood River (Figure 4). In addition to determining effects of the Rat Burntwood Diversion and to assist in Manitoba Hydro's long-term planning, the study is expected to identify those environmental impacts attributed to future development of these generating sites. While planning and design of these structures are incomplete, Manitoba Hydro's preliminary calculations (based only on energy production values) show optimum forebay levels of 810, 690, 610 feet respectively, for these three generating sites. Annual fluctuations in forebay water levels at these sites would generally be in

the order of about five feet.

4.5.4 OTHER HYDROELECTRIC GENERATING SITES - In addition to the facilities previously described, seven generating sites having a combined hydroelectric potential of approximately 5,000,000 kw have been proposed for development by Manitoba Hydro comprising Long Spruce, Upper and Lower Limestone, Gillam Island, Upper and Lower Gull and Bladder Rapids (Figure 3 and Figure 4).

Development of these proposed sites will probably have more site-specific environmental impacts on the Lower Nelson River system. The Kelsey and Kettle generating stations have already imparted changes to this area.

Manitoba Hydro has given priority to development of generating sites on the lowermost stretch of the Nelson River from Split Lake to Hudson Bay. Kettle Generating Station is in the final construction phase with 9 of 12 turbines in operation; construction has begun at Long Spruce, and preliminary engineering works for development of Upper and Lower Limestone are underway (Reference 3).

PHOTOGRAPH 2 - Esker of sand and gravel north-west of Southern Indian Lake.

PHOTOGRAPH 3 - Closed black spruce forest is common in the mid-zone of the boreal forest area.

PHOTOGRAPH 1 - Meandering streams with fast flowing stretches (left centre) between Esker hills near Southern Indian Lake.

PHOTOGRAPH 4 - Study Area bog vegetation consists of a variety of herbaceous plants, shrubs and trees. Black spruce predominates back of the willow and alder fringe.

PHOTOGRAPH 5 - Fireweed appears as a pinkish hue on the burned over areas on the north side of Southern Indian Lake.

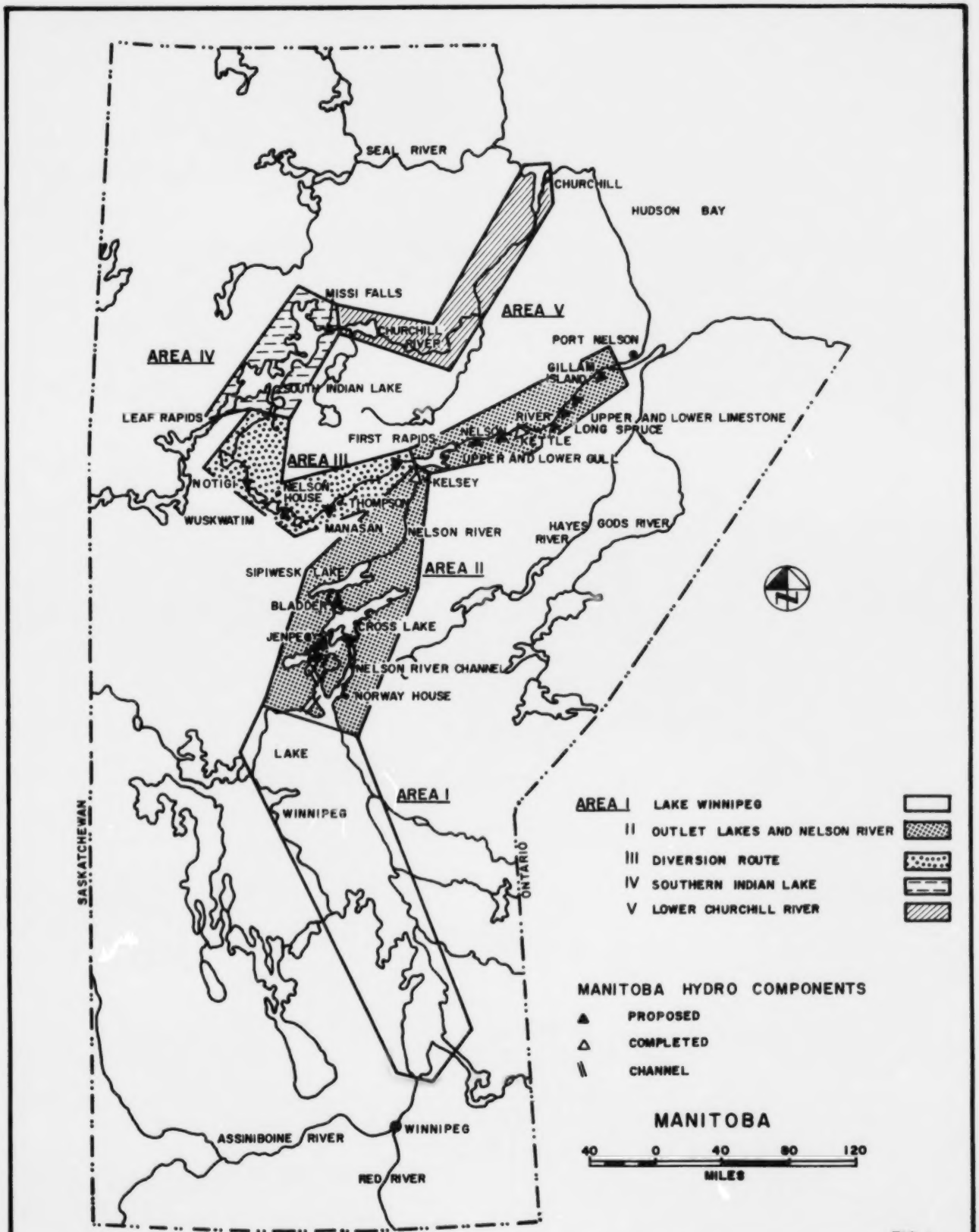


FIG. 1

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY AREA LOCATIONS

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
T. C.	S.P.	DATE JAN. 74	DATE JAN. 74	AS SHOWN	JAN. 74	1 OF 58	61 - 1 - 1025
	CHECKED F.P.						

FIG. 2

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
CHURCHILL RIVER DIVERSION

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
T.C.	S.P.	DATE JAN. 74	DATE JAN. 74	AS SHOWN	JAN. 74	2 OF 58	61-1-1025
	CHECKED P.						

NELSON AND BURNTWOOD RIVER ULTIMATE PROFILE

Approximate year of operation is indicated beside the name of each generating station.

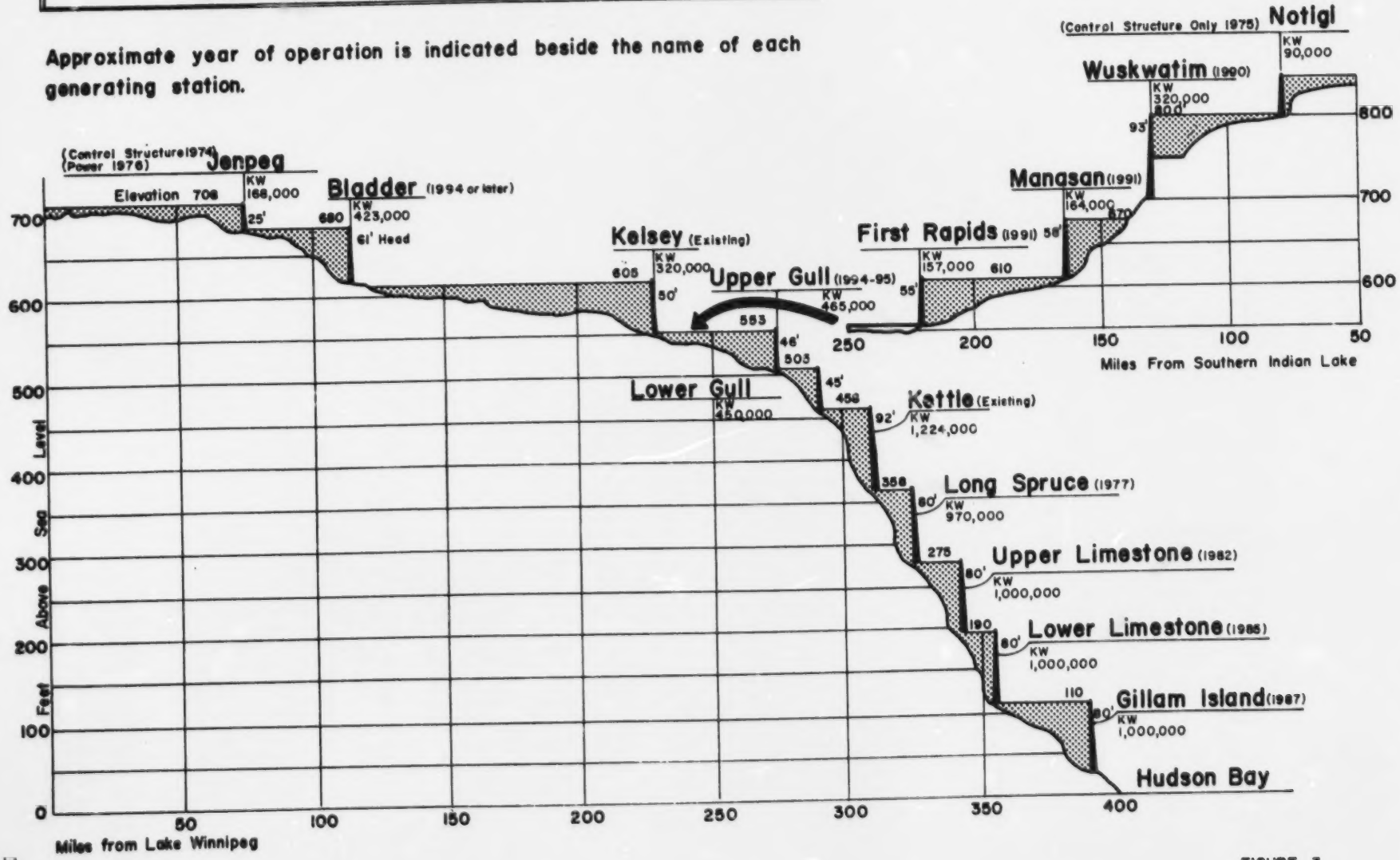


FIGURE 3

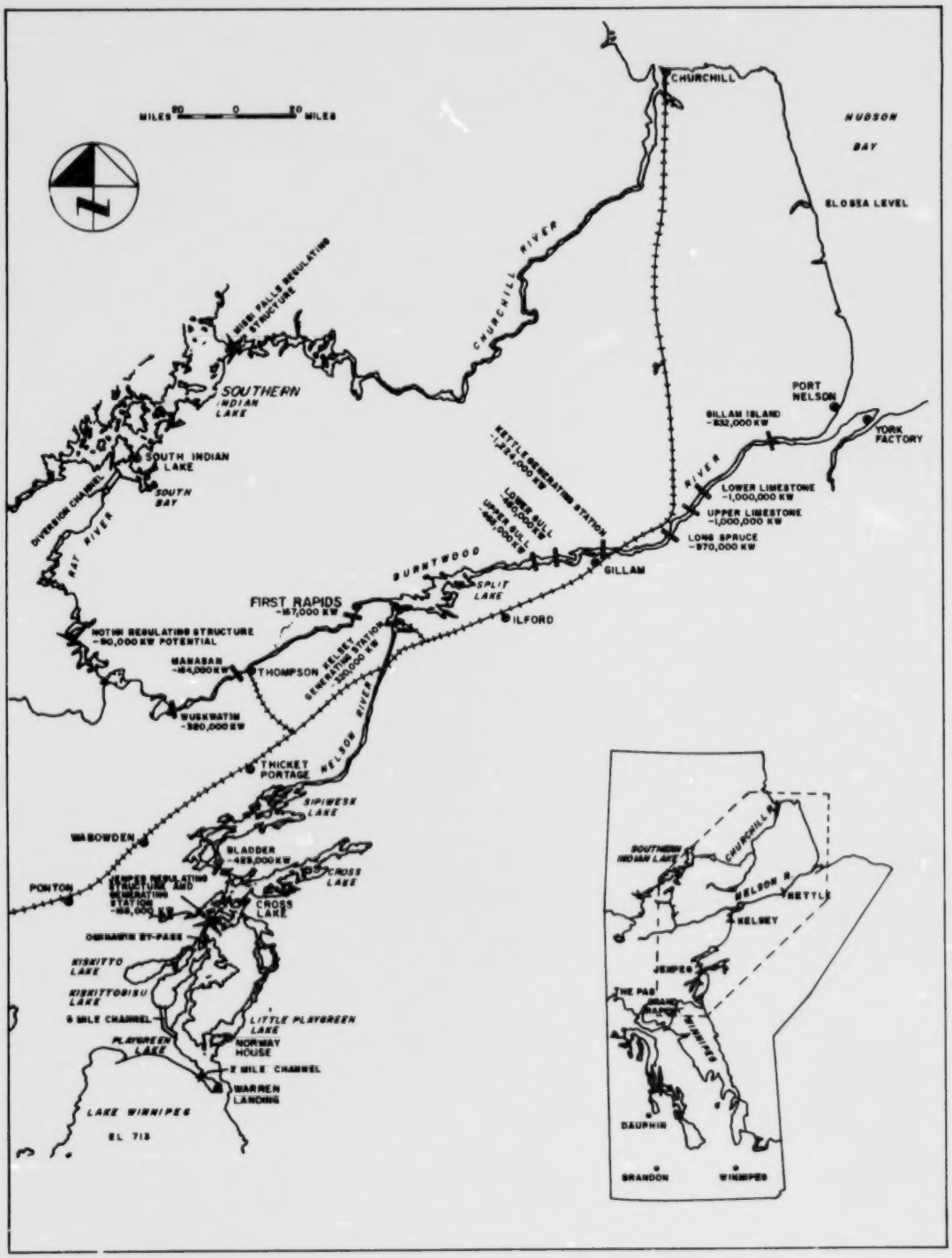
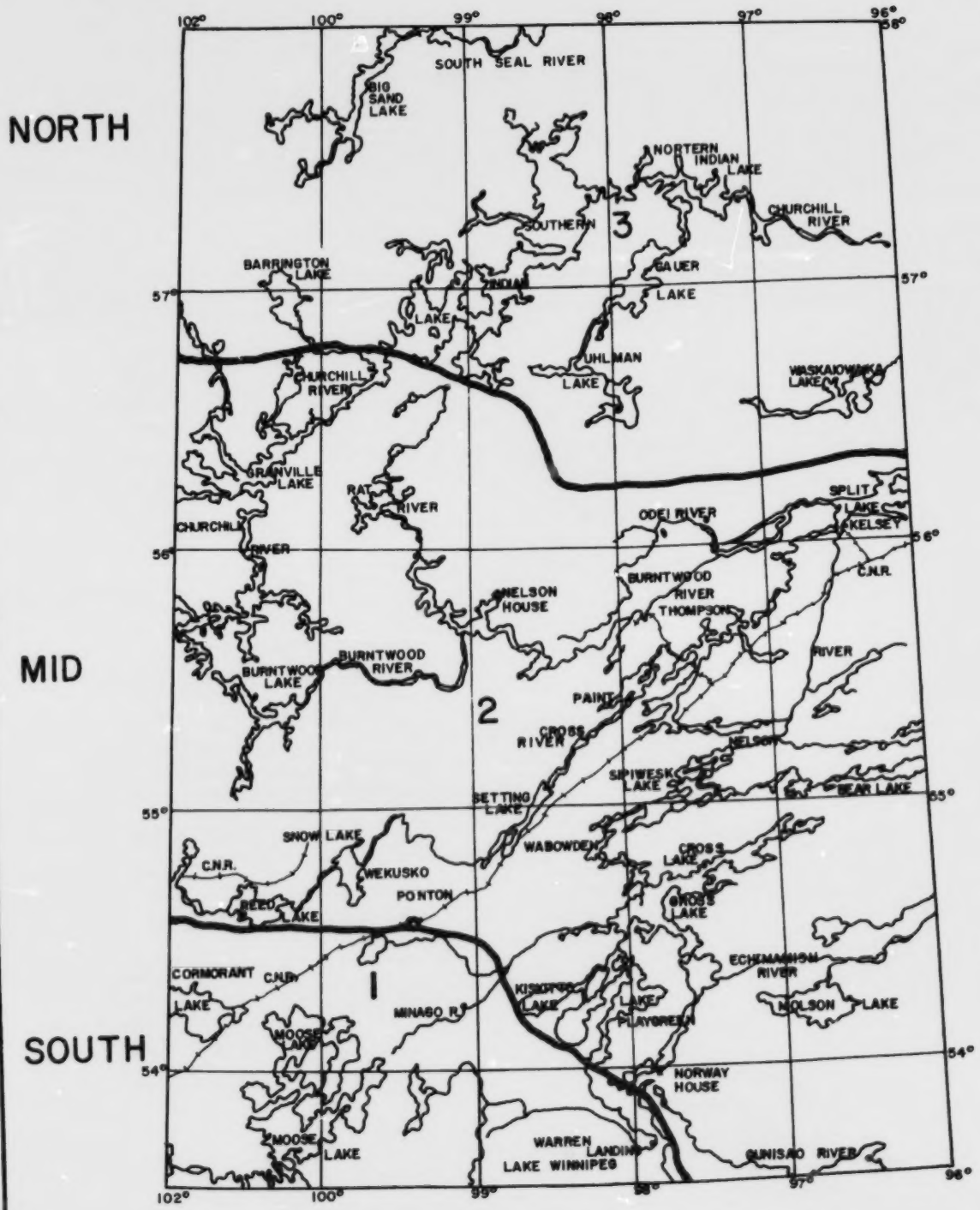


FIG. 4

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH				CANADA · MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY PROPOSED HYDRO-ELECTRIC DEVELOPMENT	
PREPARED T.C.	DRAWN S.P. CHECKED F.P.	SUBMITTED DATE JAN. 74	APPROVED DATE JAN. 74	SCALE AS SHOWN	DATE JAN.74	SHEET 3 OF 58	FILE NO. 61-1-1025



LEGEND
1. SOUTH ZONE
2. MID ZONE
3. NORTH ZONE

FIG. 5

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH				CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY VEGETATION ZONATIONS FOR THE STUDY AREA			
PREPARED T.C.	DRAWN S.P. / CHECKED F.P	SUBMITTED DATE JAN. 74	APPROVED DATE JAN. 74	SCALE AS SHOWN	DATE JAN. 74	SHEET 4 OF 58	FILE NO. 61-1-1025

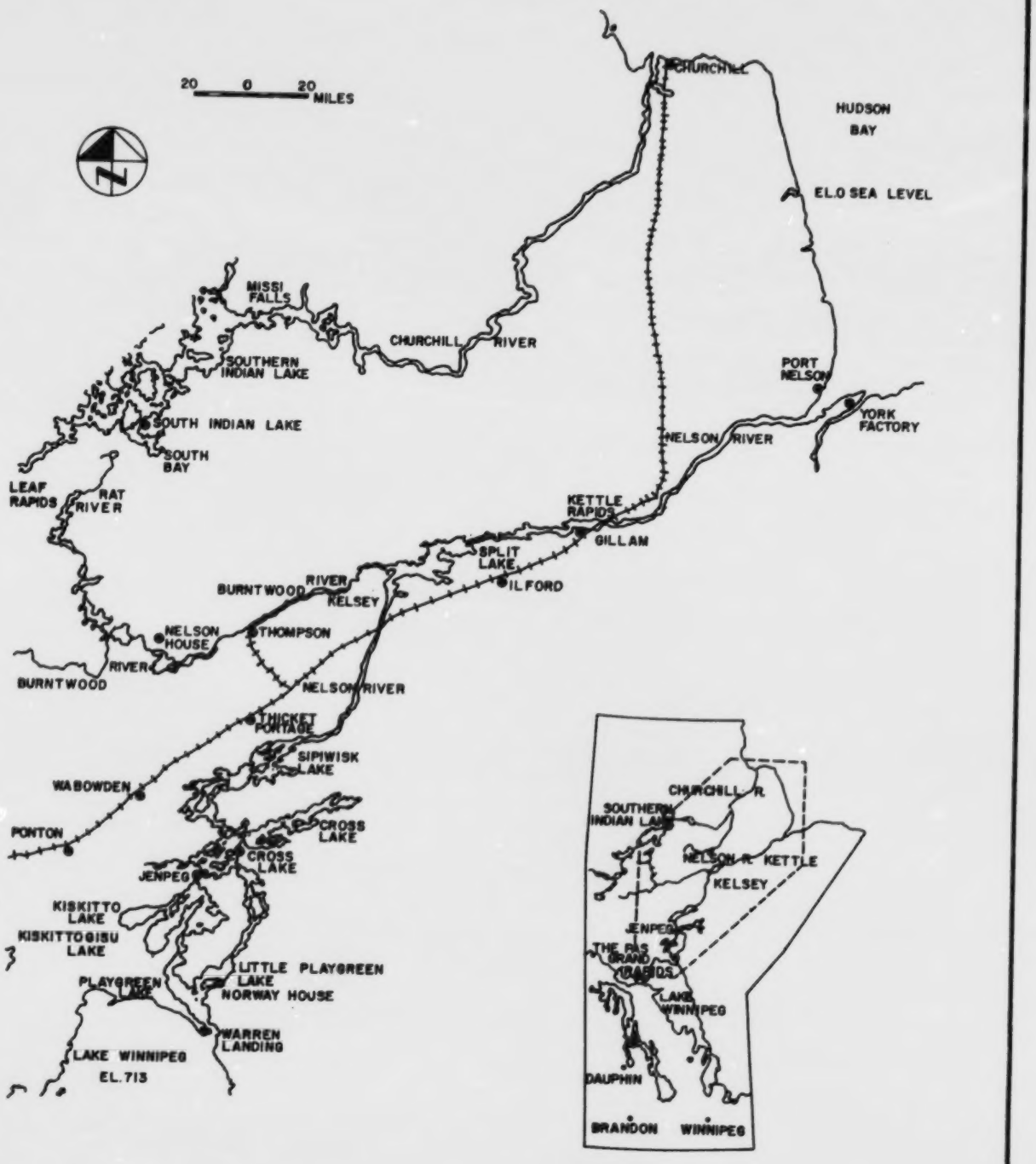


FIG. 6

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY COMMUNITY SITES

T. C.	DRAWN S.P. / CHECKED F.P.	SUBMITTED DATE JAN. 74	APPROVED DATE JAN. 74	SCALE AS SHOWN	DATE JAN. 74	SHEET 5 OF 58	FILE NO. 61-1-1025

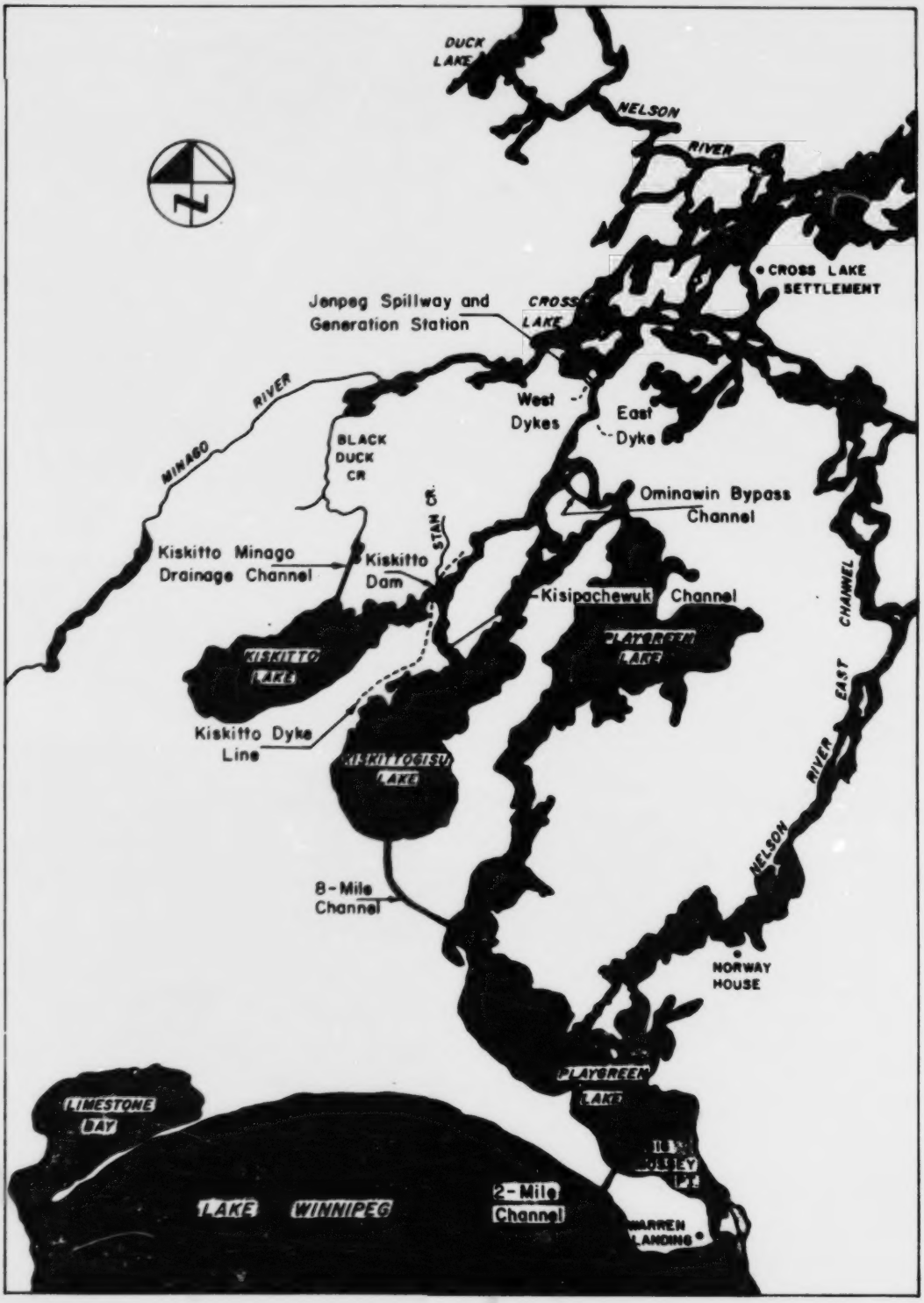
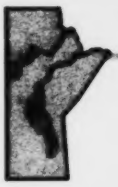


FIG. 7

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY LAKE WINNIPEG REGULATION SCHEME OUTLET LAKES AREA
PREPARED T.C. / DRAWN S.P. / CHECKED F.P. / SUBMITTED DATE JAN. 74 / APPROVED DATE JAN. 74	SCALE AS SHOWN / DATE JAN. 74 / SHEET 6 OF 58 / FILE NO. 61-1-1025



5.0 METHODOLOGY

5.1 GENERAL APPROACH

The general approach used to assess the physical impact of the proposed hydro developments in the Study Area involved four tasks.

The first task was the development of a classification system to categorize and describe shorelines and land areas to be affected in terms of their physical characteristics and vegetation.

The second task was to classify all shorelines and land areas to be affected in the Study Area in terms of the classifications systems developed as part of the first task.

The third task was to develop general impact process statements for each classification of shoreline and land area to describe how that classification might react to changed water level or flow conditions over a period of about 50 years.

The fourth task was to apply the general impact process statements to specific lakes and rivers recognizing specific levels of flooding and peculiarities of shorelines not adequately covered in the general classifications and process statements.

The carrying out of these tasks involved extensive field inspection and study of aerial photographs, both of areas to be affected and of areas which had been affected by artificial changes in water levels and flows for varying periods of time.

5.2 CLASSIFICATION SYSTEMS

Three classification systems were developed to classify the shorelines and terrain to be affected by changed water levels and flows.

A Shoreline Classification System was developed to describe existing shorelines and the backshore typically associated with each shoreline type.

A Shoreline Area Classification System was developed to describe the area in the vicinity of future raised shorelines where such future shorelines were so far removed vertically and/or horizontally from the existing shoreline that the existing shoreline and its associated typical backshore did not correctly describe the area of the future shoreline and where, in addition, it was not possible to predict with confidence which of several possible shoreline types might develop in the future.

An Inundated Terrain Classification System was developed to describe extensive areas to be inundated in the future and which would react in different ways.

The classification systems are summarized in Tables 1, 2 and 3 and defined in the following sections. The probable relationship between the elements of the three classification systems is suggested in Table 4.

TABLE 1

SHORELINE CLASSIFICATION SYSTEM

Number	Category		Classification
11 - 15	Bedrock and Bedrock-Controlled	11	Steep bedrock shoreline
		12	Vertical bedrock shoreline
		13A	Low bedrock shoreline with shallow backshore overburden
		13B	Low bedrock shoreline with deep backshore overburden
		14	Bedrock-controlled shoreline with overburden beach
		15	Low bedrock-controlled shoreline
21 - 28	Alluvium or Overburden	21	Ice-scoured till bank
		22	Shoreline in coarse grained material
		23	Clay shoreline of moderate height and mild slopes
		24	Low alluvial shoreline
		25	Shoreline in slumping overburden
		26	Treed muskeg shoreline
		27	Low shoreline in coarse sediments
		28	Low willow shoreline
31	Organic	31	Fen shoreline

TABLE 2

SHORELINE AREA CLASSIFICATION SYSTEM

Type	Classification
A	Treed muskeg shoreline area
B	Clay overburden shoreline area
C	Organic terrain in valleys
D	Glacial drift shoreline area

TABLE 3

CLASSIFICATION SYSTEM FOR INUNDATED TERRAIN

Symbol	Classification
	Sedge communities
	Treed muskeg terrain
	Treed muskeg terrain with permafrost
	Glacial drift terrain
	Bedrock outcrops
	Clay overburden

TABLE 4

PROBABLE RELATIONSHIP BETWEEN

CLASSIFICATION SYSTEMS

CLASSIFICATION BEFORE FLOODING		CLASSIFICATION AFTER FLOODING AND EVOLUTION OF NEW SHORELINE	
		Shoreline Classification	
Inundated Terrain Classification	Shoreline Area Classification	Mild Exposure to Water Waves and Currents	Severe Exposure to Water Waves and Currents
Sedge communities	C: Organic terrain in valleys	31: Fen shoreline	31 or Shoreline erodes until a different type is reached
Treed muskeg	A: Treed muskeg	26: Treed muskeg	26 or Shoreline erodes until a different type is reached
Glacial drift	D: Glacial drift	22: Coarse sediments	22 or 13, 14, 15
Bedrock outcrops		11: Steep bedrock	11
		13: Low bedrock	13
		14: Bedrock controlled	11, 13
		15: Low bedrock controlled	11, 13
Clay overburden	B: Clay overburden	23: Clay shoreline	13, 14, 15
		25: Slumping overburden	13, 14, 15

5.2.1 CLASSIFICATION SYSTEM FOR SHORELINES - The significant and typical characteristics of shoreline types, as they occur on the various lakes and river systems, were investigated in the field. Characteristics deemed significant include general morphology, stratigraphy and composition of shoreline materials; type, zonation, density and size of the vegetation; drainage characteristics; and occurrence of permafrost. While the total number of possible combinations of these factors is large, only a few combinations are common in nature. The number of typical shoreline profiles has been culled to 15. Location and extent of these types were determined by aerial photographic interpretation after complete reconnaissance flying of the whole region.

The profiles selected are described in general on the following pages; an attempt is made in the description to encompass all possible variations. The drawn profile may be viewed as a particular example of the shoreline type; the vegetation listed above includes typical vegetation from all reaches where the type occurs (Figure 8). It is noted that some combinations of vegetation are depicted which are unlikely in nature.

The profiles were drawn from the Rat-Burntwood system and the Upper and Lower Nelson and Churchill Rivers. Sections of the systems were grouped as reaches on the basis of characteristic occurrence and combination of various shoreline types. Discussion of the reaches includes description of the local variations in the physical characteristics of the profiles.

On the accompanying figures and profiles, a subscript "b" indicates the presence of an open sand or gravel beach on the profile; a subscript "m" denotes an offshore marsh

zone of variable extent. Very extensive marshes are very often marked by independent "m"'s.

The accompanying shoreline classifications are an attempt to generalize detail. The particular characteristics of individual river and lakeshores have been generalized to allow applicability along extensive systems. The precision of representation of a particular shore by its particular mapped profile is a problem.

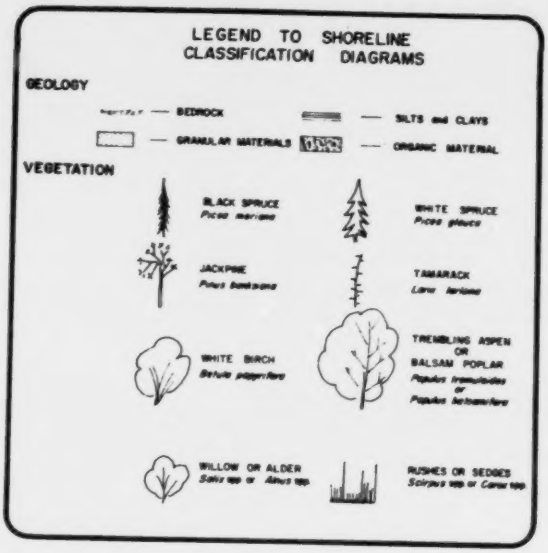


FIGURE 8

TABLE 1

SHORELINE CLASSIFICATION SYSTEM

Number	Category	Classification	
11 - 15	Bedrock and Bedrock-Controlled	11	Steep bedrock shoreline
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		22	Shoreline in coarse grained material
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		24	Low alluvial shoreline
		25	Shoreline in slumping overburden
		26	Treed muskeg shoreline
		27	Low shoreline in coarse sediments
		28	Low willow shoreline
31	Organic	31	Fen shoreline

CLASSIFICATION 11 - STEEP BEDROCK SHORELINES: Type 11 (Figure 9 and Photograph 6) characterizes a moderately irregular shoreline formed almost exclusively of bedrock sloping steeply out of the water or of bedrock and angular boulders. Outcropping bedrock (Photograph 7) predominates on the slopes, which may be an average of 30° or greater. The bedrock is typically granite, grandiorite or gneissic granite to diorite, forming steep smoothly rounded outcrops. Very shallow colluvial deposits are common on breaks in the general slope. Overburden of any significant depth is rare, appearing only in depressions in the bedrock profile, and is normally lacustrine clay or till.

Up to three indistinct zones of vegetation may exist on this profile. The first two, a bare water-washed zone and a shrub zone, if they exist at all, are very narrow. The third zone is a coniferous forest grading into the local upland vegetation.

In the first zone are found Gramineae in small scattered clumps, Campanula sp., Aster spp., Rubus idaeus and similar small herbs.

The second zone includes Salix sp., Betula papyrifera, Alnus sp., Populus tremuloides and Picea mariana in various combinations with a ground cover of Gramineae and feather mosses.

In the third and largest zone, the dominant conifers are Picea mariana, Picea glauca and Pinus banksiana. Occasionally Betula papyrifera and Juniperus communis shrubs are found. Ground cover consists of Cladonia rangiferina, crustose and foliose lichens, feather mosses, Arctostaphylos uva-ursi, Potentilla tridentata and Sphagnum spp..

Although its extent in any one area is rarely great, the range over which this profile may be found is broad including Granville, Southern Indian and Playgreen Lakes, on the Burntwood River and the East Channel of the Nelson River.

CLASSIFICATION 11

PHOTGRAPH 6 - Steep Bedrock Shoreline above Opegano Lake on the Burntwood River.

PHOTOGRAPH 7 - Steep Bedrock Outcroppings south of Missi Falls on Southern Indian Lake.

CLASSIFICATION II

STEEP BEDROCK SHORELINE

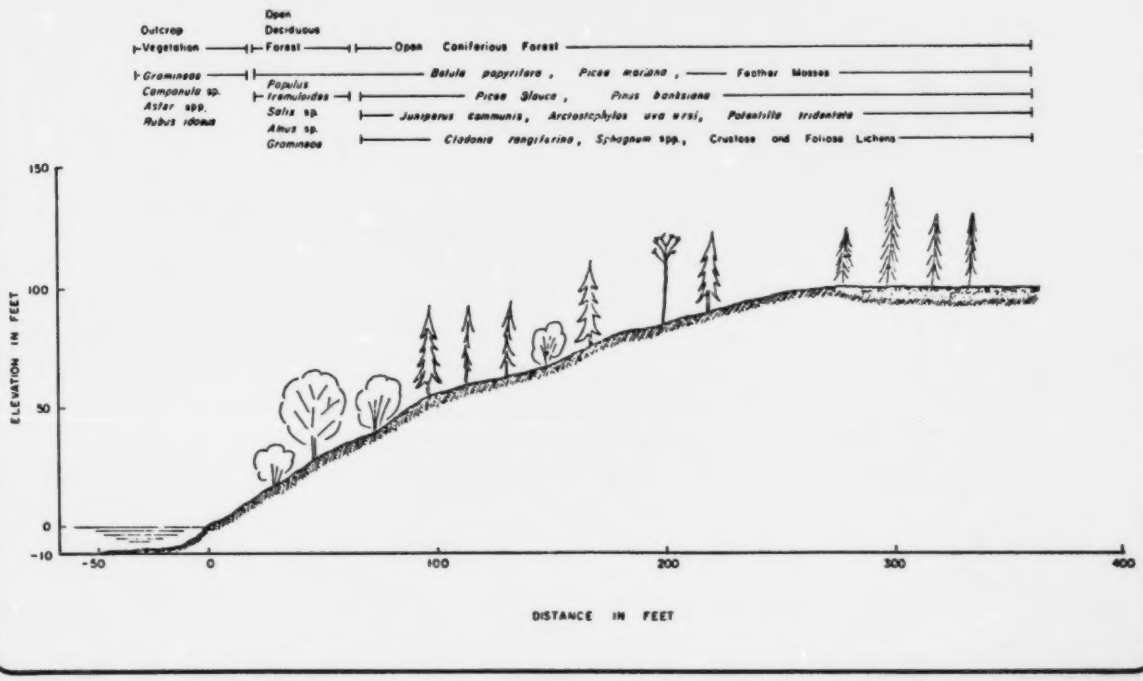


FIGURE 9

CLASSIFICATION 12 - VERTICAL BEDROCK SHORELINE: Shorelines of Type 12 (Figure 10 and Photograph 8) occur along channels entrenched in Paleozoic limestones; long stretches tend to be nearly straight. Where the rock is of reasonable quality, the shoreline will be vertical plus or minus a few degrees. As the quality of rock decreases so does the slope. The height of the outcropping rock may be as great as fifty feet. Resting on the shelf of limestone is a thick layer of glacial till (Photograph 9) which is typically permafrosted. Where the cliffs are low this till will be heavily slumped, otherwise it will slope smoothly from the face of the rock.

Dominant species leading to the uplands are Picea mariana with occasional Picea glauca and Populus balsamifera. The understory normally consists of Alder sp., and Salix sp. Equisetum, Empetrum nigrum, Kalmia polifolia, Cassandra sp., Epilobium angustifolium and Sphagnum sp., make up the ground cover. At the upper end of the profile one might find in addition to the above Larix laricina, Ledum groenlandicum, feather mosses and Cladonia rangiferina.

Shorelines of Type 12 exist in the study area only on a few miles of the Lower Nelson and Lower Churchill Rivers.

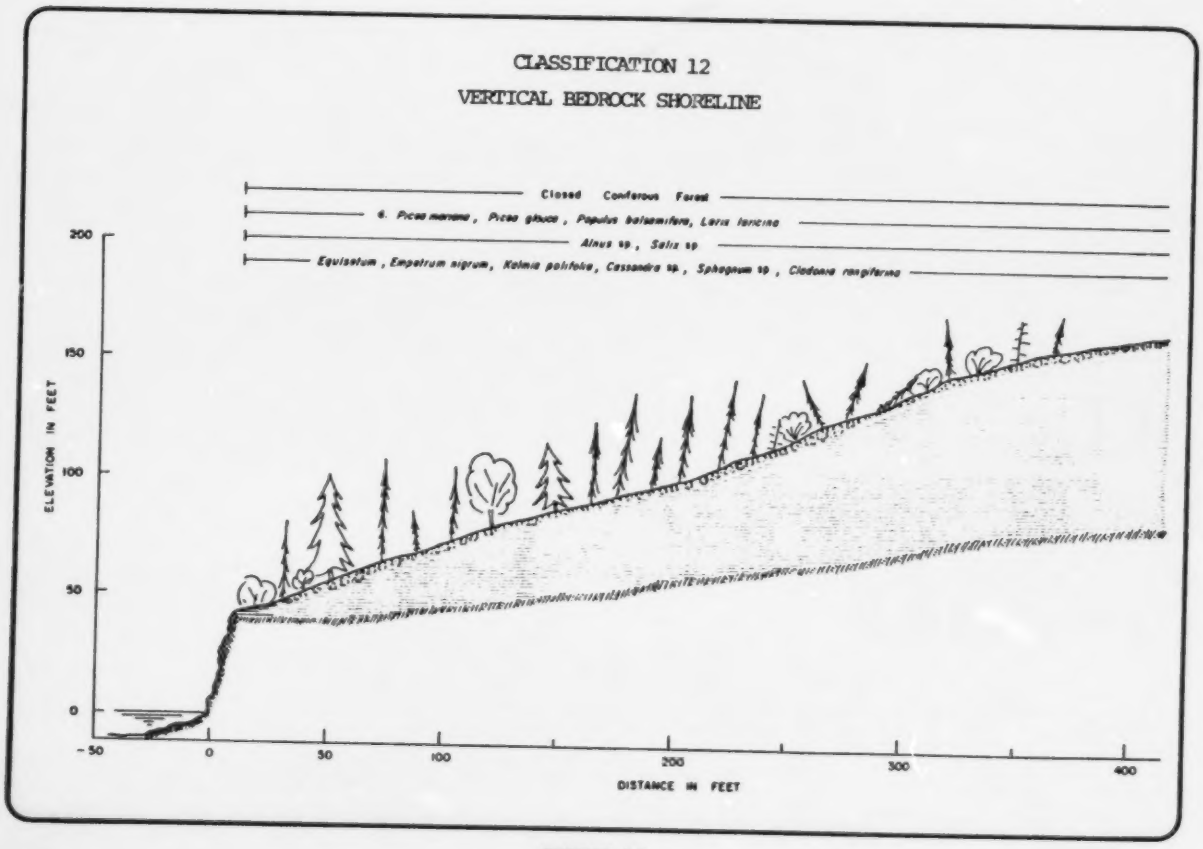
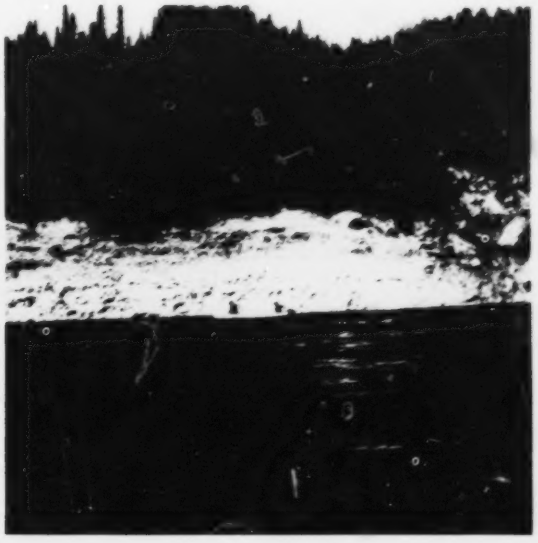


FIGURE 10

PHOTOGRAPH 8 - An aerial view of limestone cliffs in the lower canyon of the Lower Churchill River.



PHOTOGRAPH 9 - Till overlying the limestone outcrops below Bad Cache Rapids on the Lower Churchill River.

CLASSIFICATION 13 - LOW BEDROCK SHORELINE: Shoreline Types 13, 14 and 15 are associated but have significant differences at the land-water interface. Types 14 and 15 commonly occur as protected shoreline scattered among protruding headlands of Type 13.

An extremely irregular shoreline is a characteristic of areas predominated by Type 13. The bedrock, exposed continuously along the land-water interface or covered with a mantle of boulders, is usually igneous or metamorphic. The outcrops are generally wide, low and smoothly glaciated and the average water-washed zone is between 10 and 20 feet wide. Above the wave-washed zone typically one of two situations exists. These are referred to as 13A - Low Bedrock Shoreline With Shallow Backshore Overburden (Figure 11 and Photograph 10) and 13B - Low Bedrock Shoreline With Deep Backshore Overburden (Figure 12 and Photograph 11 and 12).

13A - Typically a thin, discontinous overburden of lacustrine deposits, or glacial till and colluvium covers the bedrock in the backshore.

13B - A relatively thick overburden (Figure 12) five feet or more in thickness, covers the backshore on these shorelines. Typically the exposed wave-washed bedrock rises to an overburden bank of lacustrine deposits or glacial till. The base of this bank corresponds roughly to the historic high water level for the particular lake. The overburden rises moderately often to a fairly flat plateau. Permafrost may occur particularly on north facing slopes.

Vegetation on the exposed shoreline is sparse, but may include Gramineae, Solidago spp., Campanula sp., Epilobium angustifolium, Vicia spp., and Aster spp..

Immediately behind the exposed rock is a narrow zone of scrub including Salix sp., Alnus sp. and Juniperus communis.

This grades into the third zone which may include Picea mariana, Picea glauca, Populus tremuloides, Populus balsamifera, Betula papyrifera and occasionally Pinus banksiana. An understory of Salix sp. and Alnus sp. is usually present. Ground cover includes Ledum groenlandicum, Arctostaphylos uva-ursi, Aralia nudicaulis, Cornus canadensis Viburnum trilobum, Pteridium sp., Linnaea borealis and Sphagnum sp., or feather mosses. This all grades back to the typical closed coniferous forest of the uplands.

Low bedrock shorelines are found throughout a large portion of the study area along the Rat-Burntwood, Nelson and Churchill Rivers.

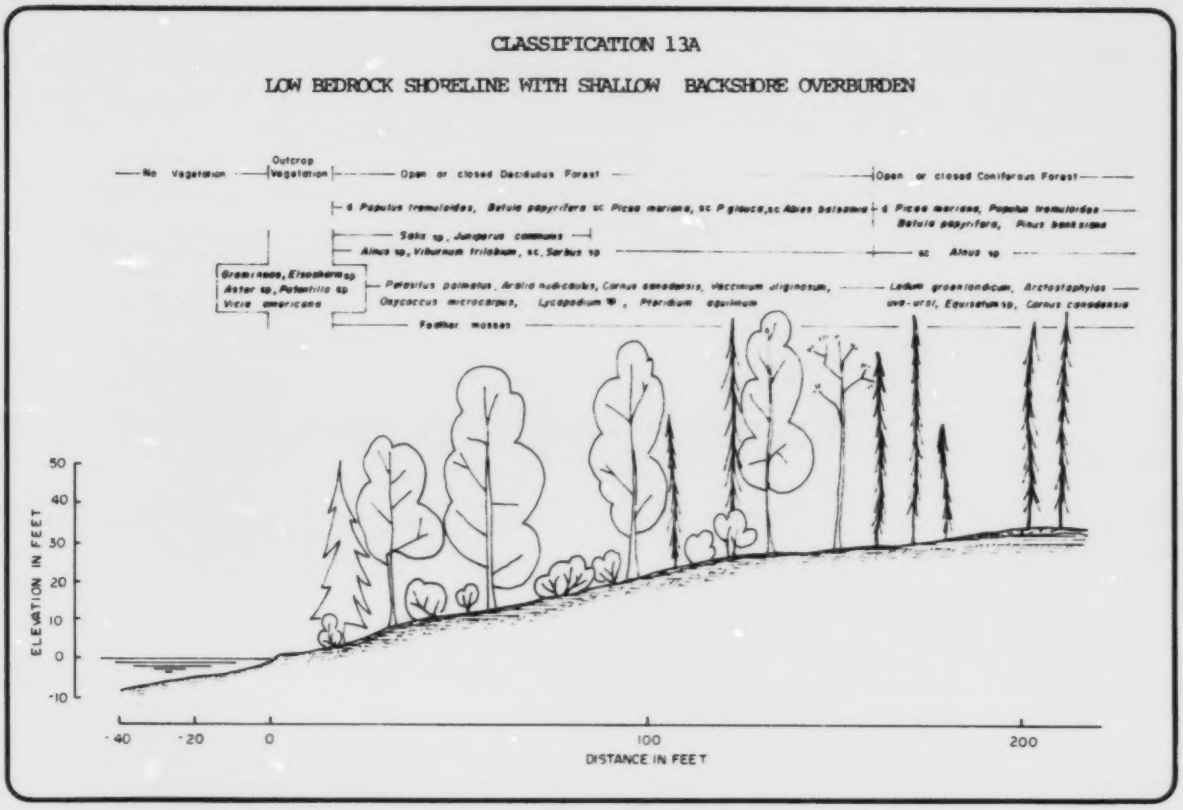


FIGURE 11

CLASSIFICATION 13A

PHOTOGRAPH 10 - Low Bedrock Shoreline With Shallow Backshore Overburden on the north end of Playgreen Lake.

PHOTOGRAPH 11 - Type 13 shoreline as found on Apussigamasi Lake.

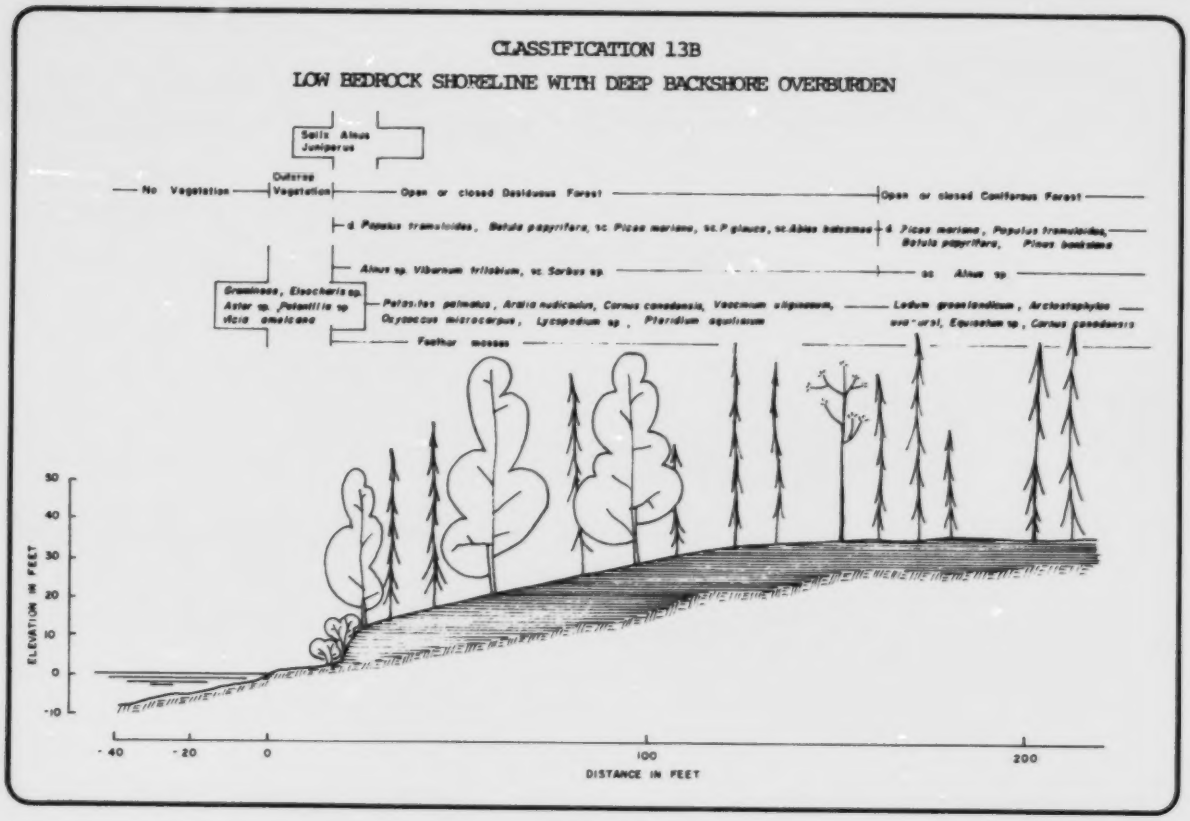
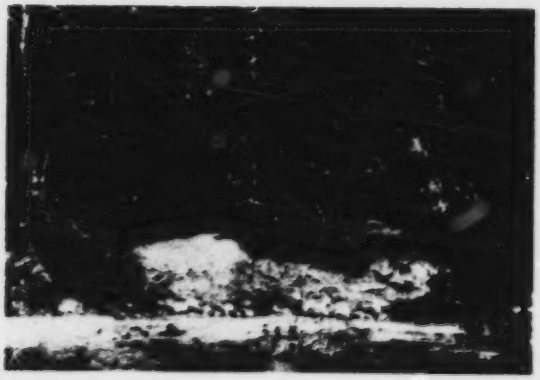


FIGURE 12

CLASSIFICATION 13B



PHOTOGRAPH 12 - A Type 13B shoreline on Wapisu Lake. The clay bank has been eroded away to the maximum water level.

CLASSIFICATION 14 - BEDROCK - CONTROLLED SHORELINE WITH OVERBURDEN BEACH: Type 14 shorelines (Figure 13 and Photographs 13 & 14) are similar to Type 13B but exhibit no bedrock outcrops except on occasion in the backshore. Overburden beaches form along relatively regular stretches of shoreline connecting bedrock promontories.

The foreshore is normally a beach of granular material or clay backed by a low clay or till bank. The overburden thinly covers the bedrock in the backshore; the slope is moderate.

Occasionally the beaches exhibit scattered scrub of Populus tremuloides, Populus balsamifera, Salix sp., Alnus sp., with Gramineae or Carex sp..

As with the previous type, backshore vegetation consists of various combinations of Picea mariana, Picea glauca, Populus tremuloides, Populus balsamifera and Betula papyrifera. Alnus sp., usually makes up the understory and the ground cover includes Ledum groelandicum, Arctostaphylos uva-ursi, Cornus canadensis, Viburnum trilobum, Cassandra sp., Kalmia polifolia and Sphagnum sp..

This shoreline type is extensive along all of the Rat-Burntwood, Churchill and Nelson systems.

CLASSIFICATION 14

BEDROCK - CONTROLLED SHORELINE WITH OVERBURDEN BEACH

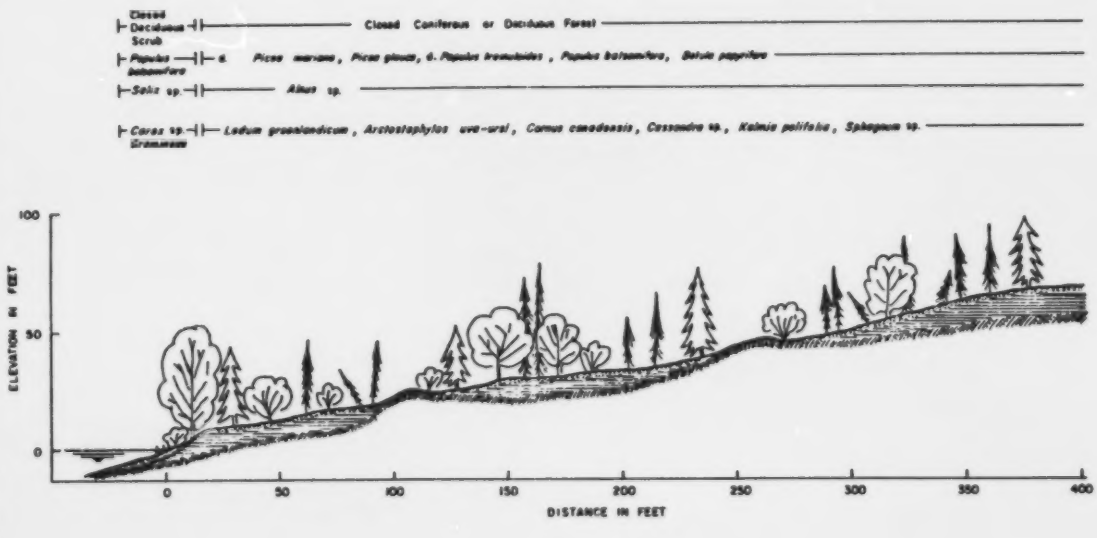
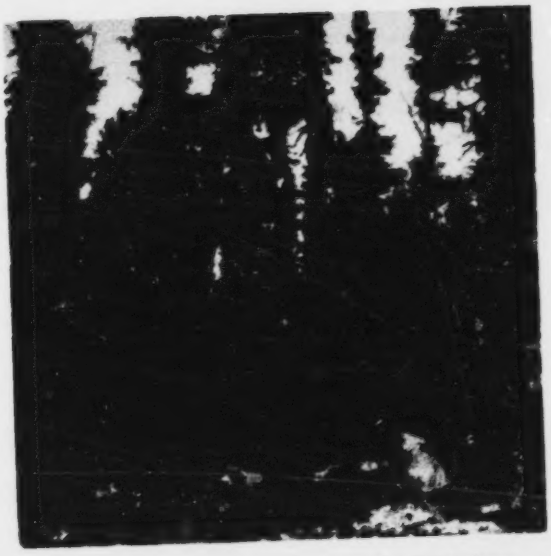


FIGURE 13

CLASSIFICATION 14

PHOTOGRAPH 13 - Bedrock-controlled river-bank below Upper Fidler Falls on the Churchill River.



PHOTOGRAPH 14 - Vegetation on the backshore near Upper Fidler Falls.

CLASSIFICATION 15 - LOW BEDROCK-CONTROLLED SHORELINE: Type 15 (Figure 14 and Photograph 15 and 16) forms moderately irregular shorelines with very narrow to nonexistant bedrock outcrops. It predominates along relatively protected shorelines.

Relief is similar to, or greater than, Type 13 and consistently less at the water's edge than Type 11. The general slope is less than 20°.

A very narrow shoreline outcrop and angular boulders of granite, granodiorite, diorite and gneissic granite, may be exposed at the water's edge; commonly the mantle of overburden drapes over the shoreline. Adjacent offshore bottom is typically clay. Overburden on the slopes and uplands is clay and silty-clay with some colluvium extending to depths of several feet or greater. A thickness of a foot of organic material is common. Topography is largely controlled by the irregularities of the bedrock surface.

Typically there is a 25 to 200 foot wide zone of deciduous or mixed wood forest along the shore, with dominant Populus tremuloides, Populus balsamifera or Betula papyrifera, and Picea mariana. Picea glauca and Abies balsamea stand are less common. In open forest a closed understory of Alnus sp., with Viburnum trilobium, or rarely Sorbus sp., develops otherwise they are scattered.

Typical herbs are Petasites palmatus, Aralia nudicaulis, Cornus canadensis, Vaccinium uliginosum, Oxycoccus microcarpus and Lycopodium spp. Ground cover is of feather mosses or Sphagnum spp.

Behind the deciduous or mixed wood zone, upland vegetation, typically coniferous forest, takes dominance.

Shorelines of Type 15 are common throughout the mapped area.

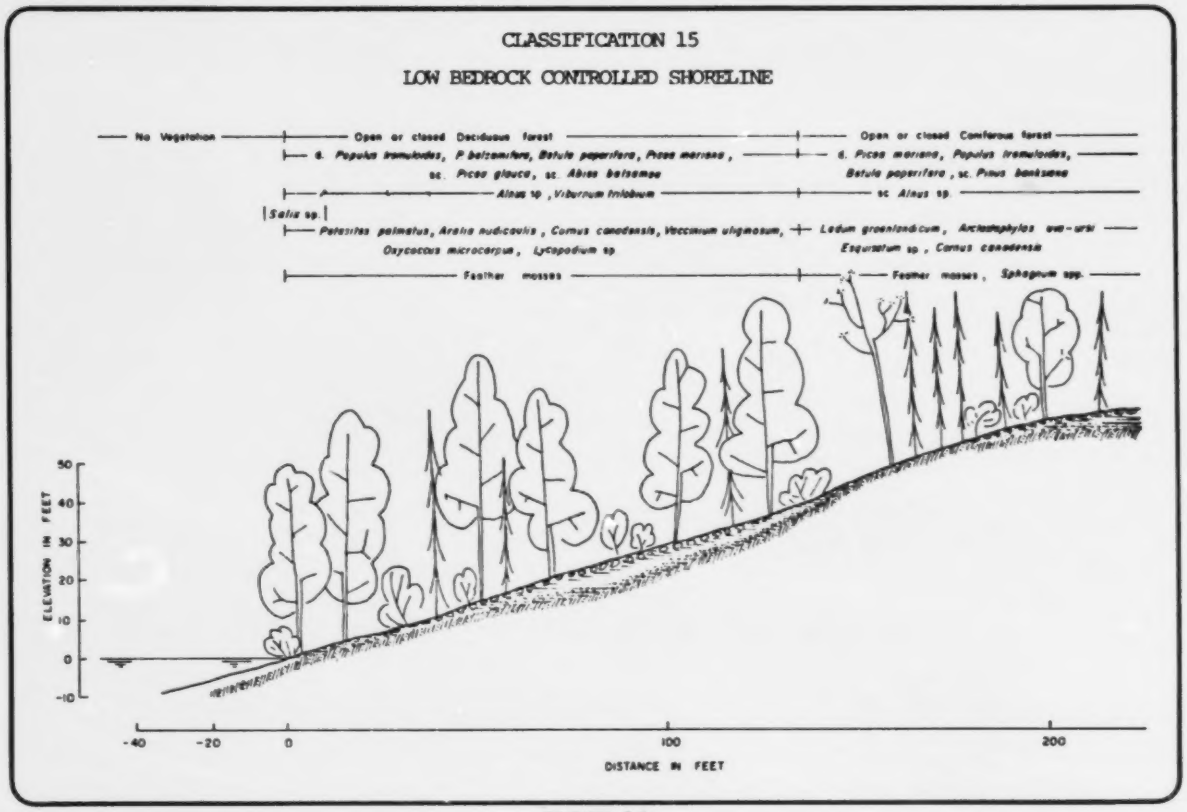


FIGURE 14

CLASSIFICATION 15

PHOTOGRAPH 15 - Vegetation along a Bedrock Controlled Shoreline with sparse outcrops found on Split Lake.

PHOTOGRAPH 16 - Continuous narrow outcrop with mixed forest along the shore on Split Lake.

CLASSIFICATION 21 - ICE-SCOURED TILL BANK: (Figure 15 and Photographs 17 and 18). This is a riverscape unique to subarctic rivers. It is common along the Lower Churchill and Nelson rivers. The result of annual ice accumulation is a zone of vegetation that is restricted in height by ice scouring action. This zone may extend as high as 45 feet above the normal water level.

The river bed is of bedrock or boulders on bedrock, and depending on the stage the bedrock may or may not show on the river bank. A deep layer of till (up to 150 feet thick) overlies the bedrock except in the lowest reaches where marine deposits predominate. The silt or clay, impregnated with permafrost, maintains steep slopes in spite of localized slumping.

At least two distinct zones of vegetation are noticeable, one below the reach of the ice and the other above the ice-scoured line. Below is found Salix sp. of small size, Gramineae and Carex sp.. This is often called a seasonal grass steppe. A closed coniferous forest, dominant species Picea mariana with occasional Populus balsamifera and Picea glauca characterize the zone above the effect of the ice. The understory here is comprised of dense Salix sp., Alnus sp., while Equisetum sp., Empetrum nigrum, Kalmia polifolia, Epilobium angustifolium and Sphagnum sp., constitutes the ground cover.

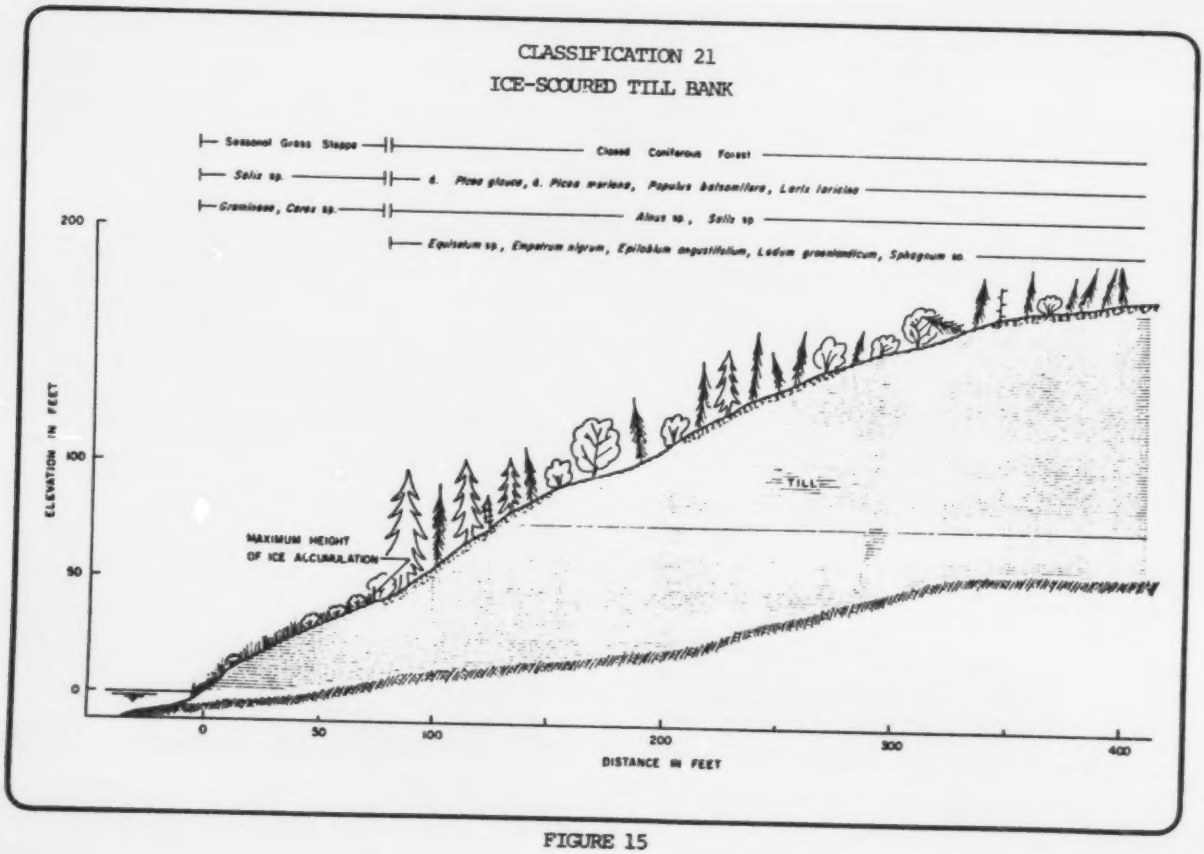


FIGURE 15

PHOTOGRAPH 17 - Ice and ice-scoured zone below Bad Cache Rapids on the Lower Churchill River.

PHOTOGRAPH 18 - This ice-scoured till bank on the Lower Churchill is heavily vegetated. Note the sharp demarkation between the seasonal grass steppe and the forest edge.

CLASSIFICATION 22 - SHORELINE IN COARSE GRAINED MATERIAL: (Figure 16 and Photographs 19 & 20). Type 22 forms regular shorelines, usually with wide sand or gravel beaches. The underlying material is ice-contact material including esker or kame deposits, glacial outwash and some coarse glacio-lacustrine deposits. The latter are not dissimilar to the sediments underlying Type 27 except in that they are thicker. In most occurrences, the materials are less well sorted sand and gravel.

Offshore vegetation is uncommon.

The sand beach may have scattered Salix sp., Myrica gale or Populus balsamifera shrubs, with Gramineae, Eleocharis sp. and Carex spp., but is commonly bare of vegetation.

Vegetation on the slopes is typically open coniferous forest of dominant Picea mariana or Populus tremuloides and with Betula papyrifera and scattered Picea glauca. Ledum groenlandicum, Vaccinium uliginosum, Cornus canadensis and Arctorstaphylos uva-ursi ane typical on the forest floor, with a ground cover of Cladonia rangiferina and feather mosses and with many bare exposures. Picea mariana typically dominates on the uplands.

Occurrences of Type 22 are typically local and isolated but it is found scattered throughout the study area.

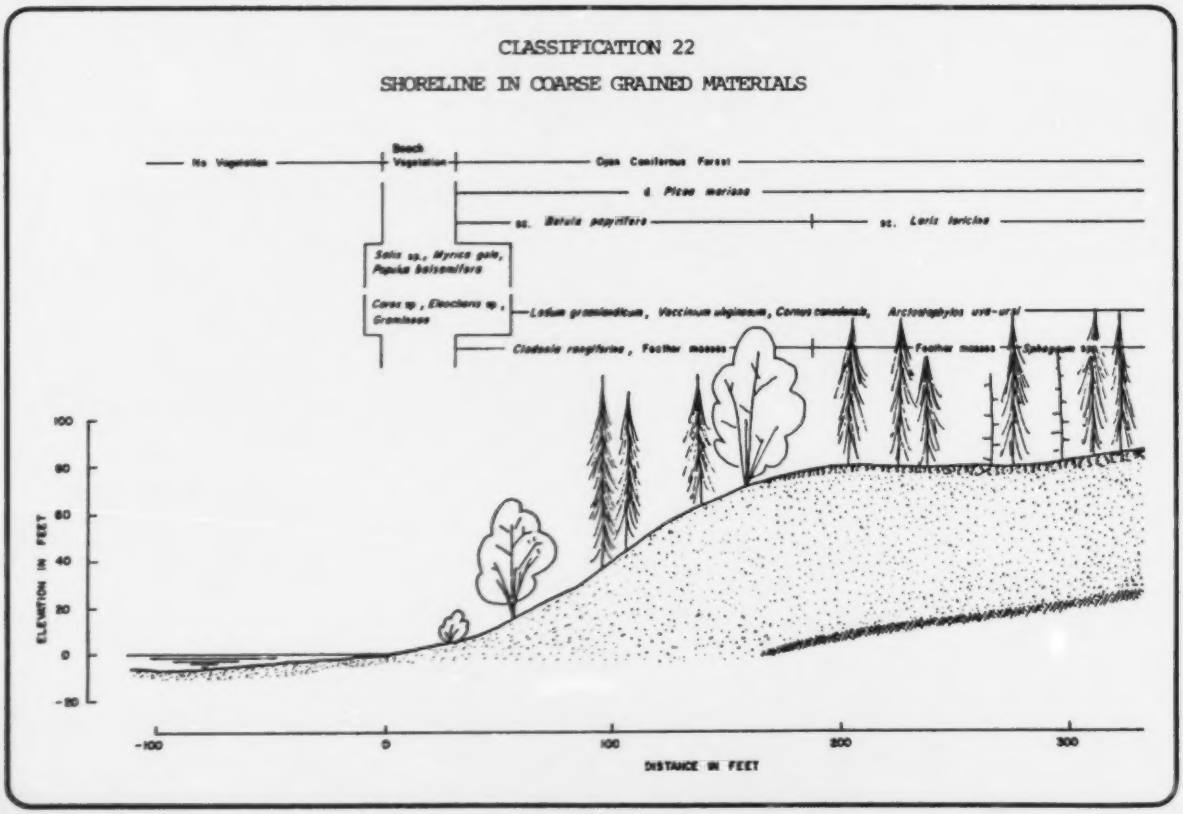


FIGURE 16

CLASSIFICATION 22

PHOTOGRAPH 19 - A beach in the south basin of Southern Indian Lake.

PHOTOGRAPH 20 - A long stretch of beach on the north shore of Moose Point on Southern Indian Lake.

CLASSIFICATION 23 - CLAY SHORELINE OF MODERATE HEIGHT AND MILD SLOPE: (Figure 17 and Photograph 21 and 22). Rivers in the study area tend to form straight or sinuous channels through erodible materials.

A masking layer of overburden about three to six feet deep over bedrock of low relief characterizes this classification. Although outcrop may be visible some distance from shore, the shoreline itself is virtually free of it. An initial fairly steep rise of about 15 feet or so is followed by a very shallow slope with poor drainage and near-muskeg type conditions on the backshore. Shoreline material is either reworked till or reworked lacustrine sediments. The silts and clays are susceptible to permafrost and where melting permafrost occurs, slumping is frequent. The slumping is not extensive - constituting about 10 to 15 percent of the shoreline length.

Excepting local variations typical shoreline vegetation would include Populus balsamifera, Salix sp., Poa sp., Carex sp., and Equisetum sp.. This shoreline vegetation forms a narrow strip extending only a few feet inshore and occasionally a very short distance offshore.

Behind this there are two main possibilities. The first is a mixed closed forest consisting of Populus balsamifera, Picea mariana, Polulus tremuloides, Picea glauca and Betula papyrifera in small numbers. This progresses into Picea mariana (dominant) and Larix laricina. The other possibility is an open forest, dominant species Picea mariana, with scattered Larix laricina.

In both cases the major understory species are Alnus sp., and Salix sp., while the ground cover is made up of Ledum groenlandicum, Clintonia borealis, Kalmia polifolia, Lycopodium sp. and Sphagnum sp..

These alluvial shorelines are found along channels of the Churchill, Nelson and Rat-Burntwood Rivers.

CLASSIFICATION 23

CLAY SHORELINE OF MODERATE HEIGHT AND MILD SLOPE

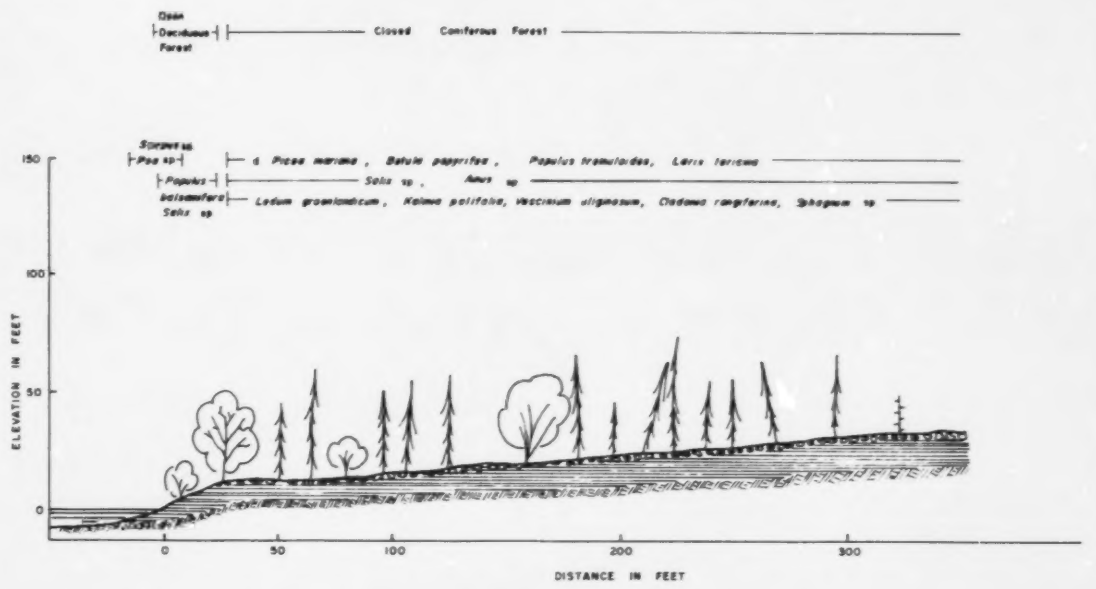


FIGURE 17

CLASSIFICATION 23

PHOTOGRAPH 21 - Heavier than normal shoreline vegetation with minor slumping on the Burntwood River.

PHOTOGRAPH 22 - Dense deciduous shrubs at the water's edge on the Churchill River.

CLASSIFICATION 24 - LOW ALLUVIAL SHORELINE: (Figure 18 and Photographs 23 and 24). The low cross-section is typical of two types of situations. One is in embayments near the mouth of very small tributaries that deposit sediments in the bays, and the other is in depositional areas along river banks. In either case, the deposits, which are normally granular, are reworked by current and waves to give a beachlike shoreline. The mild slope extends for several feet offshore and the overgrown beach may extend 100 feet inshore. The backshore is low, rises slowly and is a victim of poor drainage. Occasional potholes are found in this area. The beach material is usually granular but can be fine-grained. The finest grained sand occurs up to 300 feet backshore and frequently contains permafrost.

Offshore vegetation is mainly Carex sp., with an infringement of Salix sp.. The shoreline itself is an open deciduous scrub consisting of Salix sp., Ribes sp., with Gramineae ground cover. Beginning about 50 feet from shore is a closed coniferous forest with the dominant species being Picea mariana. Scattered Betula papyrifera and Larix laricina add to the tree community. The understory in the backshore includes Alnus sp. and Viburnum trilobum. Ground cover consists of Ledum groenlandicum, Cornus canadensis, Epilobium angustifolium, Astragalus sp., Cladonia rangiferina and Sphagnum sp..

Shorelines of Type 24 are not widespread but tend to be very productive biologically.

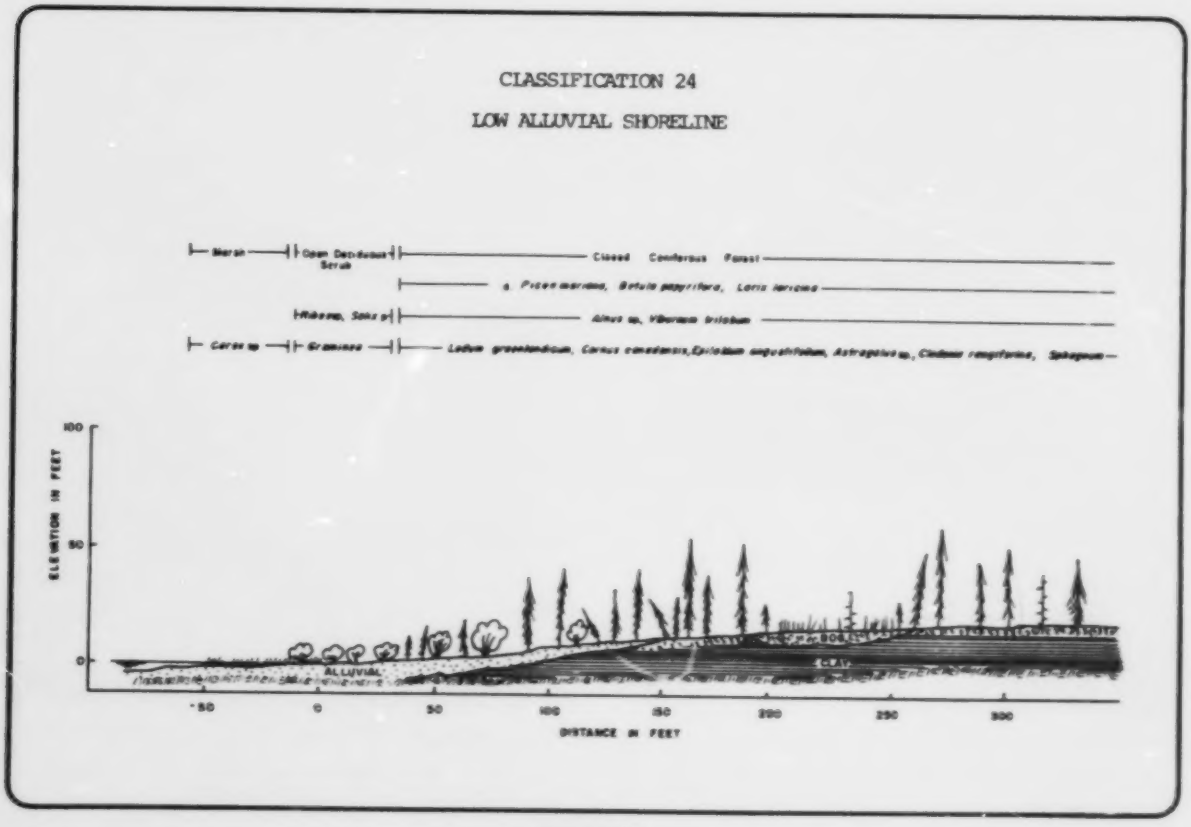
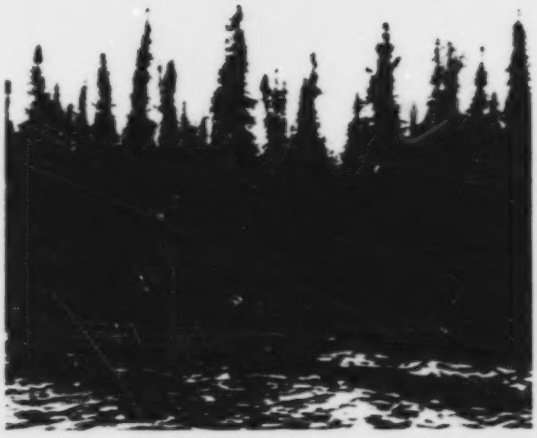


FIGURE 18

CLASSIFICATION 24



PHOTOGRAPH 23 - Shoreline below Billard Lake on the Churchill River.

PHOTOGRAPH 24 - Shoreline in the estuary of the Churchill River.

CLASSIFICATION 25 - SHORELINE IN SLUMPING OVERBURDEN: (Figure 19, Photographs 25 and 26). Type 25 is found in glacial till, marine deposits and lacustrine sediments. Silt and/or clay are normally the bank materials. Varved deposits are common. The height of the banks varies from 15 feet to 150 feet. Permafrost is the prime cause of continued instability of the banks. The slope may be 25 degrees or higher. Lack of much incident radiation allows the north facing slopes to be, on the average, somewhat steeper than those facing south. Frequently alluvial or till boulders accumulate near the toe of the slump protecting that part of the bank from all but the high flows. The level upland with its heavy organic layer harbours extensive permafrost.

The shoreline vegetation is virtually nil while that on the slope is extremely sparse - mostly due to the active slumping of the bank. The vegetation on the slope can be referred to as Steppe Shrub. The dominant species is stunted Picea mariana with occasional Picea glauca. Other shrubs are Alnus sp., and Salix sp.. Ground cover includes sparse Achillea sp., Senecio sp., Equisetum sp., and Gramineae.

The slope is not stable until the uplands are reached. Here the vegetation is better established although the growth is far from luxuriant. Depending on the location it may be classified as an Open Coniferous Forest or an Open Steppe Forest. Dominant species is Picea mariana. The understory is nonexistent while the ground cover would include Ledum groenlandicum, Andromenu glaucophylla, Vaccinium sp., Rubus chamaemorus, Cladonia rangiferina and Sphagnum sp..

This shoreline is found in the lower segment of all river systems investigated.

CLASSIFICATION 25

SHORELINE IN SLUMPING OVERBURDEN

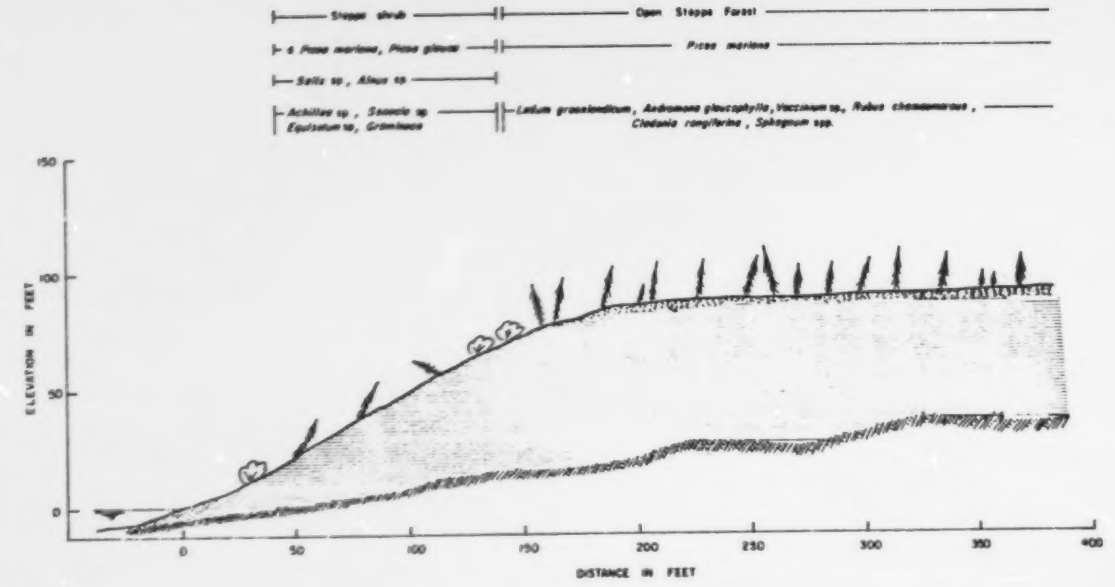


FIGURE 19

CLASSIFICATION 25

PHOTOGRAPH 25 - Slumping marine deposits on the Lower Nelson River have a varved appearance.

PHOTOGRAPH 26 - Slumping marine and alluvial deposits near Governor Island on the Lower Churchill.

CLASSIFICATION 26 - TREED MUSKEG SHORELINE: (Figure 20, Photographs 27 and 28). The shorelines of Types 26 and 27 are commonly associated; in combined occurrences, Type 27 being of somewhat greater relief and of more resistant geologic materials, commonly forms gently irregular protuberances, with Type 26 being eroded to concavities.

Treed muskeg normally forms a regular shoreline slightly concave, but may form gentle headlands.

Relief is low excepting for a steep to vertical bank immediately behind the beach. Offshore water is normally shallow for hundreds of feet out from the shoreline.

The terrain is completely underlain by lacustrine clay. Commonly a narrow beach, rarely up to twenty feet wide, forms. The sand layer is less than six inches thick and thins to less than an inch offshore. More significant sand beaches are mapped as 26b. The backshore bank formed by water action and slumping may be up to ten feet in height. The upper three to five feet is of forest peat, which deepens with increasing distance from the water's edge. Beyond 50 to 150 feet, saturated sphagnum peat of considerable depth overlies the clay. Permafrost is common.

There is sometimes an offshore marsh of Scirpus sp., 50 to 150 feet wide and in depths of two to four feet of water. Such stretches of shoreline are mapped 26m.

A narrow zone immediately offshore, and the beach are void of vegetation.

In some cases there is a narrow zone of shrubs at the top of the bank of dominant Cornus stolinifera, Salix sp. and Betula papyrifera among Picea mariana trees, with scattered Gramineae, Solidago sp. and similar herbs.

Stretching back 50 to 150 feet from the water's edge is a relatively well drained zone with open coniferous forest of dominant species Picea mariana, with Carex spp., or Gramineae, Ledum groenlandicum and other small herbs. The ground cover is predominantly feather mosses with some Sphagnum sp..

Shorelines of Type 26 are most common on the Upper Nelson River System, and occur on the North Basin of Southern Indian Lake.

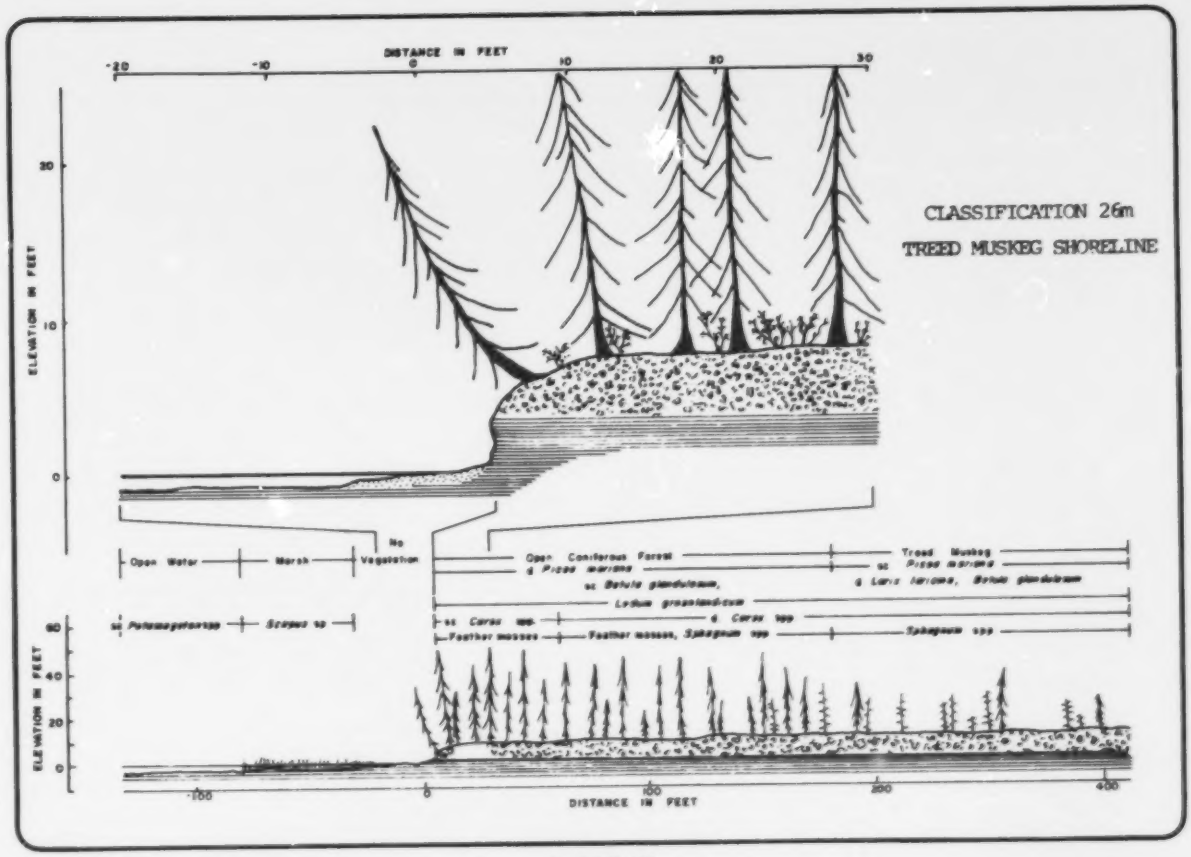
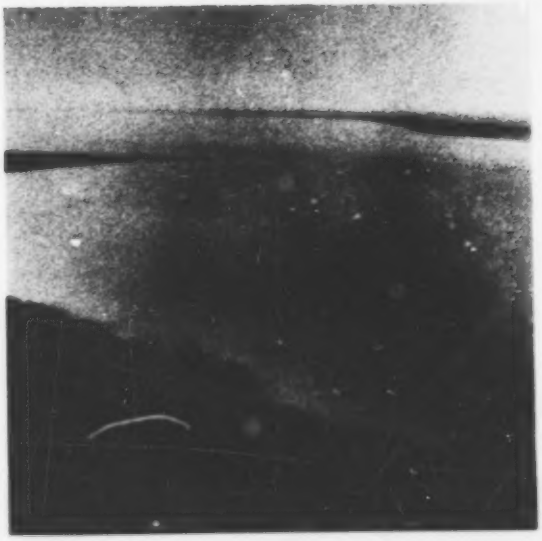


FIGURE 20

CLASSIFICATION 26



PHOTOGRAPH 27 - An aerial view of typical Treed Muskeg Shoreline on the west channel of the Nelson River.

PHOTOGRAPH 28 - Slumping of Treed Muskeg at the north end of Playgreen Lake.

CLASSIFICATION 27 - LOW SHORELINE IN COARSE SEDIMENTS: (Figure 21, Photographs 29 and 30). Shorelines characterized as Type 27 are gently irregular; relief is low but consistently higher than that of Type 26, with which they are commonly associated.

The profile is typically deeply underlain by silty clay or clay at a depth of several feet; clay commonly forms the lake bed beyond the foreshore. The sand beach is normally less than 20 feet wide and only 6 to 12 inches deep at the water's edge; however, it is occasionally 40 to 50 feet wide with a sand layer greater than 3 feet deep, thinning rapidly offshore. Where a significant sized beach has formed, the shoreline is mapped as 27b. Immediately behind the beach there is typically a steep (in the order of 20° to 30°) wave-cut bank. The rise varies between two and eight feet above the beach. Backshore, there is a surficial layer of fine to coarse sand which grades within a few feet of the surface into silty-clay or clay. Both sand and clay are typically of lacustrine origin. Overlying this is a 6 to 12 inch matt of decaying organic matter being chiefly feather mosses and forest letter. Permafrost may occur at considerable depth.

Commonly an offshore zone of Scirpus sp., grows either in a continuous belt of 50 to 200 feet wide or in large isolated stands. Shorelines with this marshy zone are mapped as 27m.

The beach and a narrow zone in shallow water offshore are typically without vegetation.

Upland vegetation extends to the top of the backshore bank. Alnus sp., are typical along the bank at the forest edge, and Picea glauca grow in scattered stands within 100 feet of the shore. The upland community is open or closed coniferous forest of dominant Picea mariana with scattered Populus balsamifera and Populus tremuloides. Some species of Gramineae, Equisetum sp., and associated herbs dominate the forest floor with Ledum groenlandicum in small clearings. Ground cover is dominantly of feather mosses.

Low shorelines of relatively coarse unconsolidated sediments are common on the Upper Nelson River, on South Bay and on the North Basin of Southern Indian Lake on the Upper Churchill River.

CLASSIFICATION 27bm

LOW SHORELINE IN COARSE SEDIMENTS

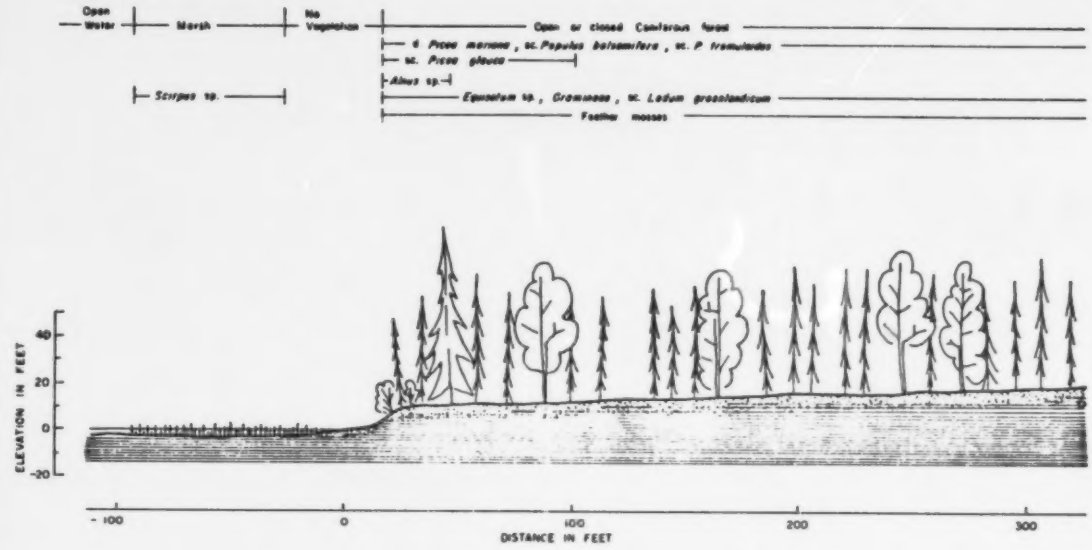
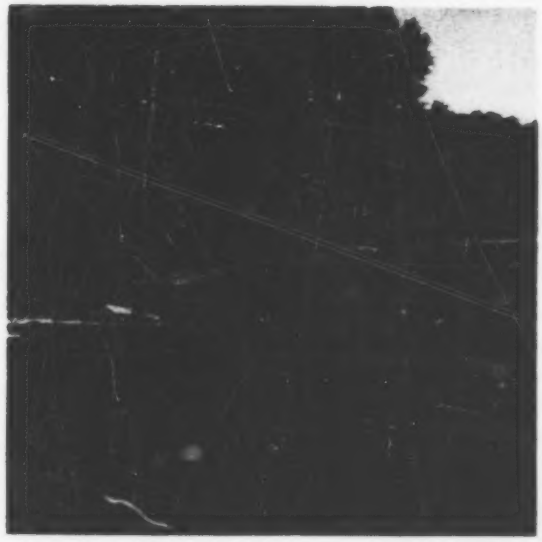


FIGURE 21

CLASSIFICATION 27

PHOTOGRAPH 29 - Dense black spruce and a few paper birch on the shore of Southern Indian Lake.



PHOTOGRAPH 30 - Trembling aspen dominates the same type of shoreline as in the above Photograph in the outlet Lakes Area.

CLASSIFICATION 28 - LOW WILLOW SHORELINE: (Figure 22, Photographs 31 and 32). Shorelines with a broad, low willow and alder zone are typically regular and concave and occur around shallow embayments. They are most commonly associated with bedrock controlled shorelines of Type 13, 14 and 15 and sometimes with treed muskeg shorelines of Type 26.

The increase in elevation of low willow shorelines is less than five feet above water level as far as 50 to 500 feet backshore before a slightly steeper rise to the uplands begins.

The low zone is over clay, silty clay, greater than ten feet deep, underlain by bedrock. The bedrock rises gently and may outcrop in the backshore; it is commonly exposed on adjacent headlands. Where such shorelines are associated with treed muskeg, depth to bedrock is normally greater. The beach area is of exposed clay, but back of it, the low zone may be overlain by up to four feet of sphagnum or forest peat; more commonly the organic layer is less than a foot thick. Permafrost occurs where the organic layer and drainage characteristics permit.

Typically an offshore zone of marsh vegetation is present; the nature of the marsh community varies significantly over the area mapped. (Where a marsh occurs, the shoreline is mapped as 28m.) It may consist of zones of Gramineae and Carex spp., commonly with Lemna sp., immediately adjacent to and onto the beach, or of offshore strands of Scirpus sp..

Width of the zones is dependent on offshore slope, Gramineae typically growing on shore and in depths of less than six inches of water, Carex spp., growing from the water's edge into water up to two feet in depth, and Scirpus sp., normally in two to four feet of water. Large marshes may extend beyond 1000 feet from shore, with complete zonation of vegetation as described above, and with Potamogeton spp. scattered throughout and beyond.

The characteristic zone of Type 28 is the broad belt of closed deciduous shrub stretching 50 to 500 feet back from the water's edge to the first slopes. It is a zone of poor drainage and commonly of standing water in small pools. Dominant species are Alnus sp., and Salix sp., shrubs, with very scattered Betula papyrifera and Picea mariana trees increasing in abundance with increasing distance from the shore. Common herbs include Mianthemum canadense and Cornus canadensis among species of Gramineae with a ground cover of feather mosses or Sphagnum spp.

Various communities may occur on the slopes beyond the willow zone; that depicted on the drawn profile must not be treated as other than one case among many.

Shorelines of Type 28 and 28m are most common on the Upper Nelson River, but occur throughout the area mapped. They are normally of little areal extent.

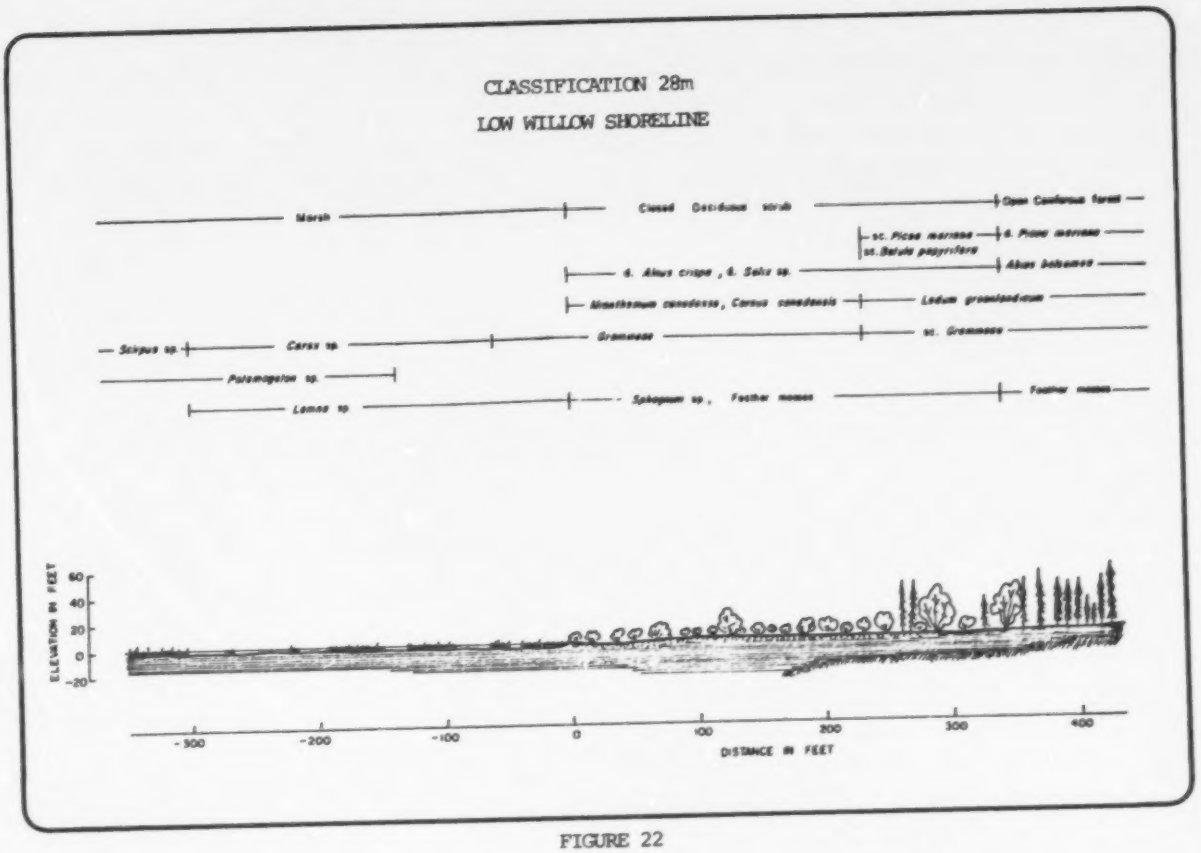
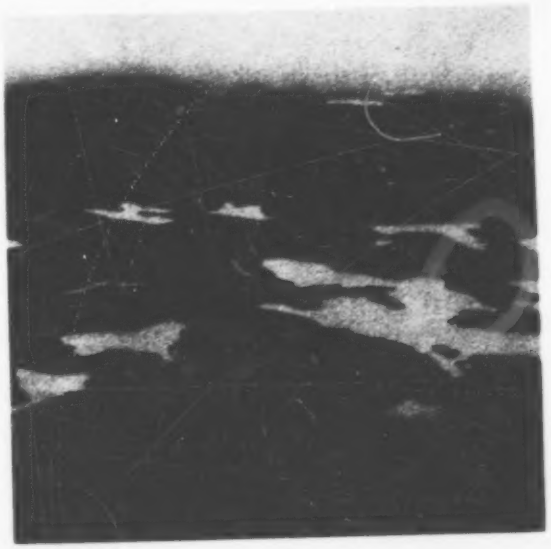


FIGURE 22

CLASSIFICATION 28



PHOTOGRAPH 31 - An aerial view shows the predominance of Low Willow Shoreline along the Upper Rat River.

PHOTOGRAPH 32 - A close-up of vegetation in a marsh on Cross Lake.

CLASSIFICATION 31 - FEN SHORELINE: (Figure 23, Photographs 33 & 34). Shorelines of Type 31 erode to long, sweeping concavities; local topographic highs in the underlying mineral material create the only inflexions in the general curve A surveyed slope of a typical fen on Kiskitto Lake was less than one degree, and a local mineral palsa rose less than two feet above the fen. Most palsas rise less than 10 feet above the local landscape.

Wave action on the fen-water interface creates a broad beach and low backshore ridge. The ten to thirty foot wide beach continues out into the lake at about two degrees. The ridge is about twenty feet wide and less than two feet above lake level. It is composed of material similar to that of the beach plus abundant willow fragments. The fen of saturated peat behind the ridge extends for hundreds of feet to several miles. It is a thin layer of saturated but consistent fen peat over an unknown (probably tens of feet) depth of saturated organic material without significant internal consistency. This is presumably underlain by the same lacustrine clay that forms many of the raised palsas. Low permafrost palsas of sphagnum peat over clay, or of clay, or of clay and silt occur as "islands" within the general fen. They differ radically in composition and vegetation from the fen, but will not be described herein. The fen itself is not permafrosted.

The beaches are barren of vegetation.

Vegetation on the backshore ridge is a deciduous orthophyll shrub community of dominant Salix sp., subdominant Myrica gale and scattered Equistetum sp..

The fen is a meadow of dominant Carex sp., with Equistetum sp., Drosera intermedia and similar bog herbs, and very scattered Myrica gale shrub.

Such fens are found along the mapped river systems only on Kiskitto, Kiskittogisu and Southern Playgreen Lake.

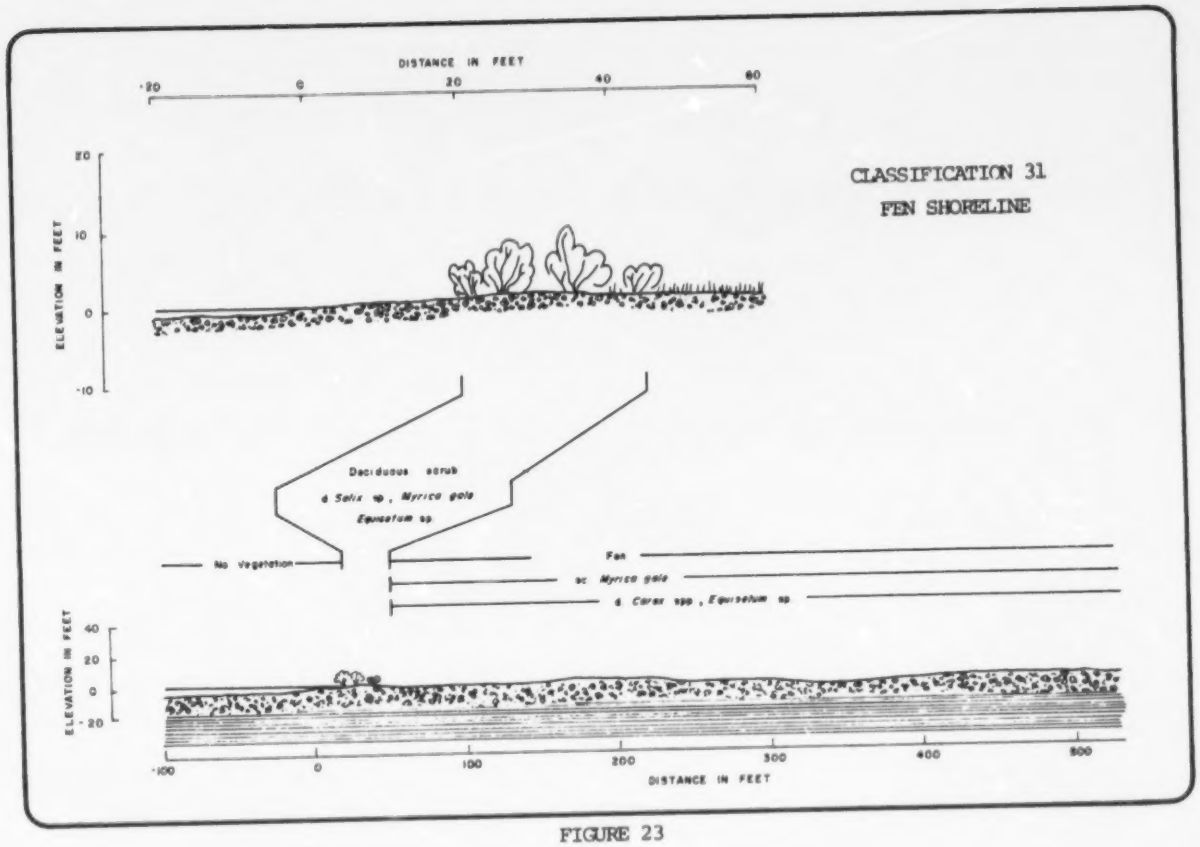
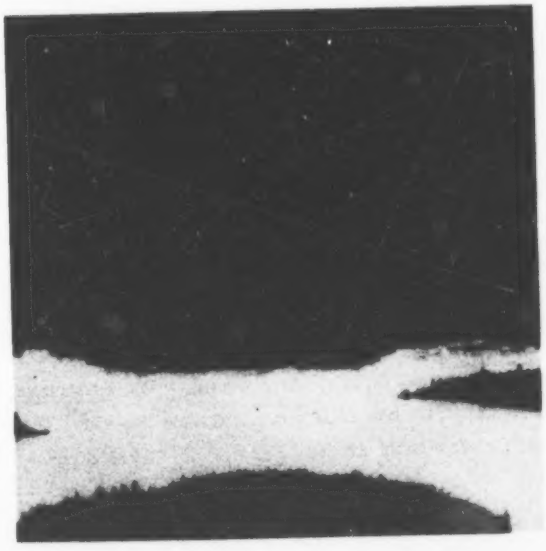
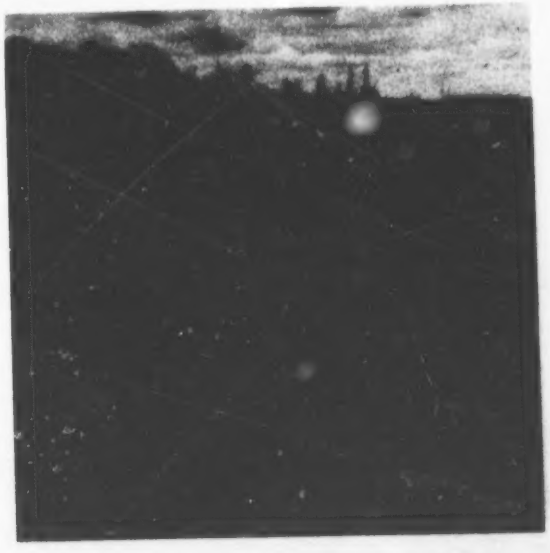


FIGURE 23

CLASSIFICATION 31



PHOTOGRAPH 33 - A Kiskitto Lake fen with mineral palsas. One palsa is on the shoreline; the others are well back in the fen.



PHOTOGRAPH 34 - Fen vegetation on a Kiskitto Lake shoreline.

5.2.2 CLASSIFICATION SYSTEM FOR SHORELINE AREAS - During the course of the study, it was found that in some cases the classification of the existing shoreline was not satisfactory as an indicator of the future shoreline which might be expected to develop. This typically applied where the depth of flooding was such that the terrain at the future water line was different from that at the existing water line. In some of these cases it was not possible to predict with confidence the type of shoreline which might evolve in a certain type of terrain. For example, an increase in water level of 20 feet opposite a treed muskeg shoreline might place the future water line opposite a clay slope. If the depth of overburden were not known it would not be possible to predict the extent to which bedrock would be exposed by future erosion and thus the future shoreline type. For these reasons the shoreline classification system was expanded (Table 2) primarily for the Churchill River Diversion Route above Notigi. The expansion was also applied, where necessary, on Southern Indian Lake and Footprint Lake.

TABLE 2

SHORELINE AREA CLASSIFICATION SYSTEM

Type	Classification
A	Treed muskeg shoreline area
B	Clay overburden shoreline area
C	Organic terrain in valleys
D	Glacial drift shoreline area

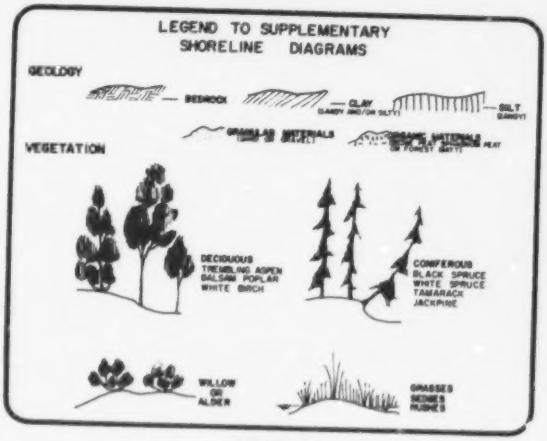


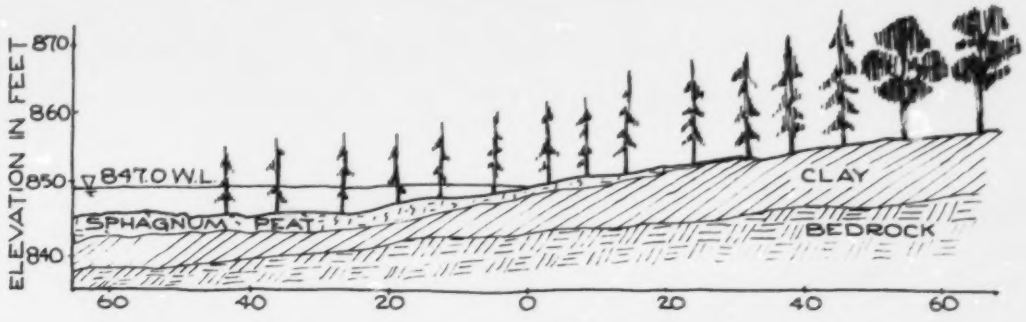
FIGURE 24

The criteria used to categorize the additional shoreline types were slope, plant community composition, and depth and type of overburden. All these variables would influence the time required for the shoreline to achieve a natural state condition. The inundated offshore slope and vegetation would determine the amount of erosive wave energy to reach the new land-water interface. The effects of this accelerated erosional force would depend upon the shoreline slope, materials and vegetation. The inundated mild to moderately sloped forested land would be the greatest deterrent to stabilization processes. With regard to materials, the depth of the mineral and/or organic overburden was unknown. The additional classifications are hereafter termed "Shoreline Areas".

CLASSIFICATION A - TREED MUSKEG SHORELINE AREA: (Figure 25). These sites are typically poorly drained low lying areas where the excess moisture is instrumental in establishing this type of organic terrain. A thick peat deposit covers the mineral soil which is usually clay of an unknown thickness. The dominant plant community is black spruce with a shrub understory and Sphagnum moss ground cover. The Sphagnum moss is the chief contributor to the thick organic mantle.

The better drained muskeg within the study area can be expected to permafrosted. Such sites fit the description of Treed Muskeg Terrain with permafrost. These terrain units will only

form discontinuous stretches of the new shoreline. The majority of the impacted muskeg sites are too wet to be permafrosted.

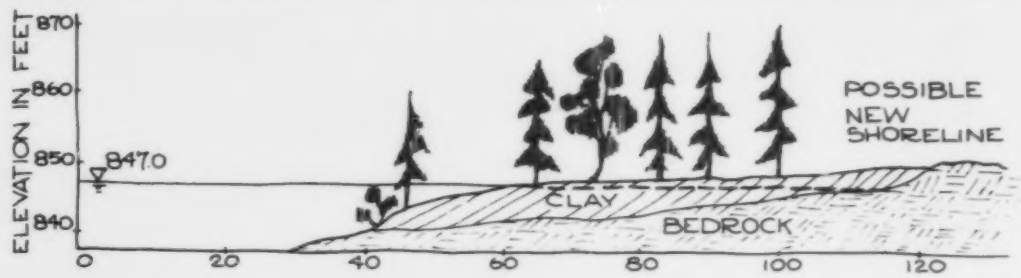


CLASSIFICATION A: TREED MUSKEG SHORELINE AREA

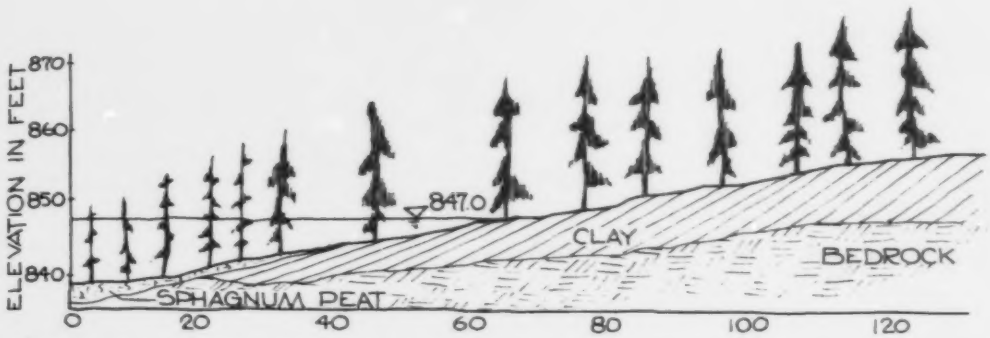
FIGURE 25

CLASSIFICATION B - CLAY OVERBURDEN SHORELINE AREA: (Figure 26). Along this shoreline area, the new water line contacts a clay overburden. The clay overlying the bedrock is of varying thickness but is considered to be of sufficient depth to make the classification of the final shoreline difficult. This overburden is expected to be at least five feet deep. Such sites are characteristically moderately sloped and well drained. These conditions are not conducive to the establishment of treed muskeg terrain. At all sites the organic soil horizon is thin. The mineral soil supports good tree growth. The forest species composition will depend upon past distrubing factors, fire being the most influential. Burnt over areas may be colonized by fire species: white birch, trembling aspen or jack pine. The extent of the fire species colonization will depend upon the topographical conditions of the area. The clay overburden terrain of the upper reaches of Rat River differs from the rugged exposed bedrock terrain of the lakes along the southern part of the river system. Within the upper reaches fire species colonize predominantly the south facing slopes while in the lower reaches the fire species colonize all well drained surfaces.

Within the discontinuous permafrost zone, north facing slopes of all reaches can be expected to be permafrosted. This is primarily a function of local microclimate conditions, depth of overburden and the insulating properties of plant cover. A typical permafrosted area would be a well forested site, with a thick layer of feather moss overlying the deep mineral soil.



SHORELINE AREA COMMON TO LAKES ON RAT RIVER ABOVE NOTIQI

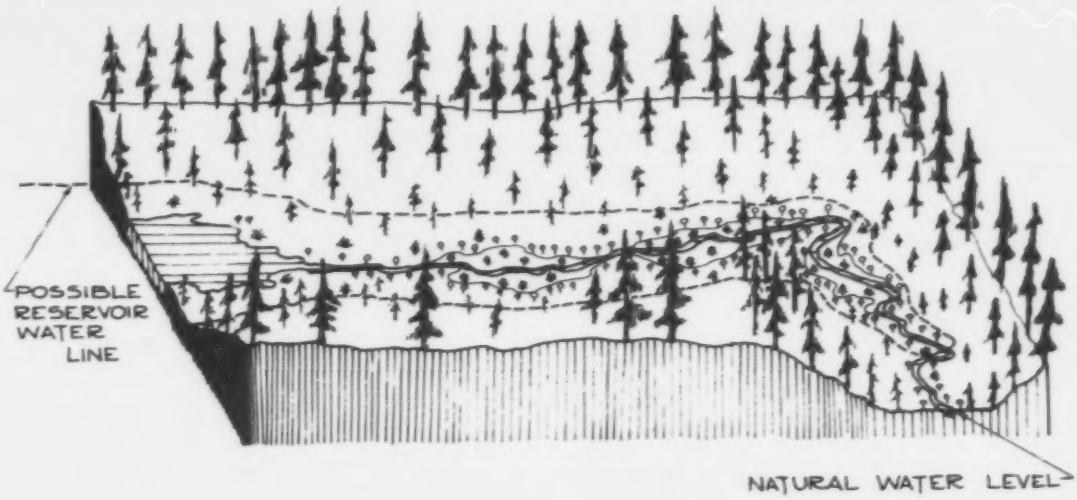


SHORELINE AREA COMMON TO RAT RIVER

CLASSIFICATION B: CLAY OVERBURDEN SHORELINE AREA

FIGURE 26

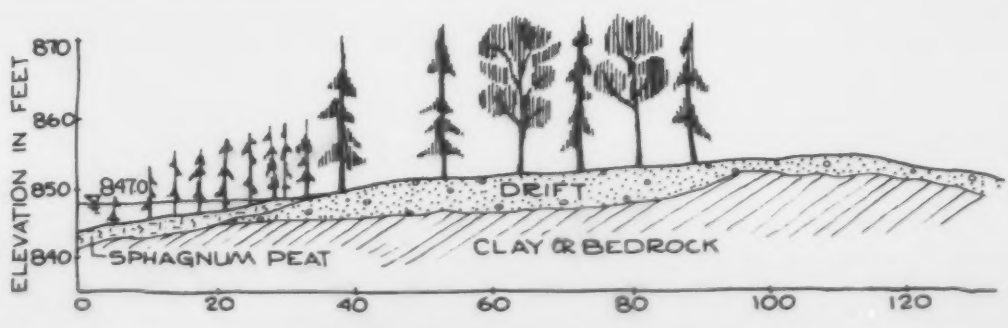
CLASSIFICATION C - ORGANIC TERRAIN IN VALLEYS: (Figure 27). This classification is characteristically a topographic low or valley type situation. In all cases, the slope is negligible to mild. As a consequence the exact extent of back flooding into the valley is difficult to determine. Normally the area is drained by an intermittent or permanent stream. These stream systems are normally densely colonized with aquatic plants and sedges, while willows often border the shoreline. The local terrain units will consist of a variety of bog, fen and muskeg areas. Back shore areas are normally higher better drained sites with a variety of slopes and overburden materials. In most cases these shorelines are located in the back areas of the reservoir.



CLASSIFICATION C: ORGANIC TERRAIN IN VALLEYS

FIGURE 27

CLASSIFICATION D - GLACIAL DRIFT SHORELINE AREA: (Figure 28). The new water level contacts what is described as a drift deposit. These deposits are low and hummocky in nature; the depth is presumed to be shallow. The material, basically a till, consists of an assortment of granitic boulders, sand and gravel. The amount of clay mixed into this unconsolidated mass is unknown. Due to the porosity of the materials, the site is well drained. The tree growth on such sites is good in comparison to the stunted black spruce on the adjacent treed muskeg areas. Poplar is the predominant tree species on these sites, the stands are open and contain little ground cover. The organic overburden if present is very thin.



CLASSIFICATION D: GLACIAL DRIFT DEPOSIT

FIGURE 28

5.2.3 CLASSIFICATION SYSTEM FOR INUNDATED TERRAIN - The Inundated Terrain Classification System was developed to describe extensive areas that will be flooded and which may be affected in various ways. The classification system to be used is presented in the following table:

TABLE 3

CLASSIFICATION SYSTEM FOR INUNDATED TERRAIN

Symbol	Classification
	Sedge communities
	Treed muskeg terrain
	Treed muskeg terrain with permafrost
	Glacial drift terrain
	Bedrock outcrops
	Clay overburden

CLASSIFICATION - SEDGE COMMUNITIES: (Mapping Symbol). The climate, topography and materials of northern Manitoba are all conducive to the formation and perpetuation of Sedge Communities. These communities consist of both bogs and fens. The dominant pioneer plant cover of the young saturated terrain is sedge, Carex spp.. Once a consolidated sedge matt is formed over water it may be colonized by species of Sphagnum moss, shrubs of the Ericaceae family and willow species along with larch and black spruce. The colonization processes are typically carried further on bogs than on fens.

A variety of bog and fen types can be recognized in Northern Manitoba. Charles Tarnocai (Reference 10) identified fen types as being either horizontal, patterned, sloping, floating, spring or collapse scars. Certain types are confined to specific regions. Collapse scars occur in the northern discontinuous permafrost zone while patterned fens are an Outlet Lakes Region phenomenon. All others exist over a wide geographic range. Bog types have been classified as being either domed, plateau-like, flat, bowl or blanket. Domed bog landforms are associated with permafrost upheaval processes. They are referred to as palsas. Plateau-like landforms, termed bog plateaus, are associated with a peat accumulation process in the Outlet Lakes Region while the peat plateaus are a result of upheaval by permafrost occuring in the discontinuous permafrost zone.

Of all types examined in the study area, only the younger successional stages of the flat and bowl bogs were classified as Sedge Communities. All other bogs were more mature and, therefore, identified as Treed Muskeg Terrain. The fens mapped as sedge communities were those existing along bodies of water off the major lake and river systems and, therefore, were not classified as Type 31 shorelines.

In general, fens are located on margins of lakes and streams in an open drainage system while bogs are land locked in a closed drainage system. These sedge communities may be sparsely populated with trees, but all growth is stunted. The sedge community peat depth and composition will vary depending upon past and present floral composition, all environmental influences and the age of the peatland. The saturated nature of the fen sites prohibits the establishment of permafrost which is evident in some bog types. A variety of aquatic plants usually flourish along the offshore areas of sedge communities.

All the continuous sedge matts are mapped within a closed line. Collapse scars are indicated by using both Sedge Community and Treed Muskeg Terrain symbols. The individual scars were too small and numerous to map individually.

The sedge communities are found throughout the entire study area.

CLASSIFICATION - TREED MUSKEG TERRAIN: (Mapping Symbol $\times x$). This terrain unit is characterized by a thick accumulation of peat over mineral soil together with a significant forest cover. The underlying material is normally lacustrine clay but may be granular.

The peat composition itself is a function of past and present floral communities. The matt can be of sedge, Sphagnum moss or forest peat origin. Depending upon the site the accumulated peat may be stratified. The lower stratum may be a sedge peat overlain by a Sphagnum peat followed by a forest peat. Sites that have gone through a fen successional processes will contain a sedge bottom. This becomes very crucial when considering the flooding impact.

In this terrain unit the dominant tree cover is black spruce with an Ericaceae shrub understory and Sphagnum moss substrate. On these poorly drained wet to saturated areas, the tree distribution and size is limited by the excess moisture. As a consequence, the stand pattern is usually broken or stringy. The enhanced tree growth along peat ridges is indicative of better surficial drainage conditions. The nature of the Sphagnum growth results in a hummocky ground cover, with the depressions normally being saturated. In the open and drier areas, the substrate is normally colonized by a species of Cladonia, a lichen commonly called reindeer moss.

This terrain unit forms the majority of the area to be inundated within the study area.

CLASSIFICATION - TREED MUSKEG TERRAIN WITH PERMAFROST: (Mapping Symbol $\triangle^{\nabla}$). This treed muskeg terrain is distinguished from that described earlier by the presence of permafrosted peat. The peat composition will in all likelihood be of Sphagnum moss origin. The underlying material is usually clay but may be granular.

The dominant tree cover is black spruce with an Ericaceae shrub understory and Sphagnum moss substrate. The drainage is such that the area is not saturated but just moist. As a consequence, the spruce stands are moderately uniform in growth and distribution. The forest may be open or relatively closed. The Sphagnum moss cover creates a hummocky surface with patches of Cladonia colonizing the drier areas.

In these areas of localized permafrost, the Sphagnum moss acts as an ideal insulator. As a consequence, the active layer is shallow. The permafrost zone itself may extend down into the mineral soil. These terrain units are permafrosted due to the better drainage and local micro-climate. A considerable number of permafrosted sites investigated in the field were topographic lows. At these sites melt-water was frequently observed running into a lake or river. Within the discontinuous permafrost zone, the topographic low areas are in all likelihood conducive to the establishment of permafrost. Here the cooler than normal summer temperatures are felt to be crucial for the establishment and existence of these ice zones.

Within the study area, derelict permafrosted landforms can be recognized as collapse scars-rounded grassy-like areas surrounded by trees. These symetrical concavities are a result of the melting out of permafrost. This thawing action may be triggered by any physical disturbance. Such potholes are sporadically located through the permafrosted muskeg sites and are in various stages of colonization, the dominant successional species being sedges. The combination of scars and treed muskeg terrain are mapped using Treed Muskeg Terrain and Sedge Communities symbols. This terrain classification would include bogs elevated by permafrost action, identified as palsas and peat plateaus.

This terrain unit is only found in isolated patches. It normally does not form a large uniform area within the Study Area.

CLASSIFICATION - GLACIAL DRIFT TERRAIN: (Mapping Symbol °°°°). Along the Churchill River Diversion route concentrated depositions of drift have been identified along the southwest sides of ridges and hills. These mounds of unconsolidated granitic boulders, sand and gravel are of a glacial depositional origin. The depth of such materials is unknown but presumed shallow. Southwesterly trending esker formations are usually found in the same general locality.

These drift areas are well drained due to overburden texture and to elevation. As a consequence, the good tree growth is in strong contrast to the stunted tree growth on adjacent lower saturated areas. Due to the permability of the materials, the ground is sparcely vegetated and the trees are widely spaced.

These terrain units were only recognized along the Rat River between Issett and Karsakuwigamak Lake.

All sites mapped as drift areas were identified from aerial photographs, black and white stereo pairs and infrared imagery. The material presence was confirmed with surficial geological maps. None of the sites were investigated while conducting the ground research.

CLASSIFICATION - BEDROCK OUTCROPS: (Mapping Symbol ^^^^). Since the study area lies within the Canadian Shield, the outcroppings are predominantly granitic in nature. Exposed rock surfaces are the direct result of past glacial activities. During the Pleistocene era the higher outcroppings were scraped, gouged and polished by the advanicing glaciers. Since the last glacial retreat, little colonization has occurred on the exposed rock. Lichens inhabit the majority of the surface while mosses and flowering plants colonize sites where the organic soil layer has accumulated. The present tree species composition will depend upon past fire disturbances. Aspen and jack pine normally recolonize burnt-over areas before spruce.

Tree distribution on the bare rock is concentrated along the joint-like structures, where chemical and mechanical erosion processes are breaking down the rock allowing for the establishment of trees.

The amount of exposed bedrock varies in each geographical area.

CLASSIFICATION - CLAY OVERBURDEN: (Mapping Symbol ⊐⊐⊐). The majority of bedrock in the Study Area is covered with lacustrine clay of varying thicknesses. The present depth of overburden may have depended on the relative location of the site in Lake Agassiz during the depositional period, the site relief and all post-glacial erosion processes.

These terrain units are well drained and have a variety of slopes. In fact, the occurrence of this terrain unit is a function of slope. Moderately inclined terrain is usually well drained. The site will not generate any significant amount of organic overburden. The thick peat deposits typical of other poorly drained sites are absent. However, the overburden will support good tree growth. The species will depend on the geographic area and past disturbances. The climax forest cover is black spruce but there may be mixed and pure stands of poplar, white birch, jackpine or white spruce.

Within the discontinuous permafrost zone north-facing slopes can be expected to be permafrosted. This moist environment allows for a shallow feather moss cover that is of insulating value to the underlying frozen overburden. The permafrost zone may extend down to bedrock.

This terrain unit is common to the entire Study Area.

5.2.4 CLASSIFICATION SYSTEM FOR RIVER CHANNELS - Generally river channel shorelines are classified according to the same system as that developed for shorelines.

There is a significant difference between lake and river shoreline erosion. The river flow provides the mechanism for shoreline formation by erosion, and in contrast lake shorelines display characteristics due to wave action. River channels considered in this report generally have velocities of flow greater than one-half foot per second, while lakes have a velocity less than this. A special case is Birch Tree Lake on the Thompson River where diversion will result in significant velocities. Here, both current and wave effects will be important.

All shoreline classifications except the Fen Shoreline (Type 31) occur along channels in the Study Area. Clay Shorelines of Moderate Height and Mild Slope (Type 23) and Ice Scoured Till Banks (Type 21) are peculiar to river channels. Bedrock and bedrock controlled category shorelines are the most common and occur along each river. The various alluvium or overburden categories (Types 21 to 28) occur in various combinations depending on the geographical area. Clay Shorelines of Moderate Height and Mild Slope (Type 23) and Shorelines in Slumping Overburden (Type 25) occur along the Rat and Burntwood River, with some occurrence of Low Willow Shorelines (Type 28) in wider areas of the channel. Alluvium or overburden categories along the Upper Nelson River channels are generally of low relief and poorly drained (Types 26, 27 and 28). Along the Lower Nelson River shoreline of the alluvium or overburden categories are generally Ice Scoured Till Banks (Type 21) or Shorelines in Slumping Overburden (Type 25). Shorelines of the alluvium or overburden categories along the Churchill River channel are mainly Clay Shorelines of Moderate Height and Mild Slope (Type 23) and Shorelines in Slumping Overburden (Type 25) in the upper reaches and Ice Scoured Till Banks (Type 21) and Shorelines in Slumping Overburden (Type 25) form above the Upper Canyon to the Mouth at Hudson Bay.

5.2.5 DEFINITION OF WATER LEVELS AND FLOWS - Water levels and flows in this report for the various components of the Nelson, Churchill and Burntwood River systems are based on data from various reports prepared for the Lake Winnipeg, Churchill and Nelson Rivers Study Board. The main exceptions are water and ice elevations on the Rat-Burntwood River System which were derived from the Manitoba Hydro "Report on Water and Ice Elevations in the Rat-Burntwood River System, December 1973". Similarly, the extent of the drawdown of the Notigi forebay under various operating conditions and the variation in the level of the Lower Nelson River with discharge were obtained from various Manitoba Hydro plans and memoranda. Finally, the levels of the Churchill River from Leaf Rapids to Southern Indian Lake were approximated from the variety of sources listed in the "Water Levels and Flows - Leaf Rapids to Missi Falls" section.

One may define four water level or flow conditions as follows:

- Natural flows: These are flows which would occur in a state of nature without any control structures or diversions in upstream areas.
- Recorded flows(Historic flows): These are flows which have actually occurred and have been measured over some time period. They are natural flows modified by whatever controls or diversions exist at various times during the period of record.
- Modified Historic flows (Present use): These are flows which would have occurred if all the controls and diversions which exist at the present time had existed for the total period of record. They differ from recorded flows to the extent that existing controls and diversions have been imposed progessively during the period of record. These flows are sometimes termed "historic flows modified according to present use".
- Regulated flows: These are projected future flows computed on the basis of a specified sequence of development of controls and diversions.

Except in the case of Lake Winnipeg, the difference between natural, recorded and modified historic conditions is small compared to the difference between any one of these conditions and the regulated condition. Hence, for the purposes of this report, natural, recorded and modified historic conditions are considered to be similar, and are termed "natural conditions". The reported "natural conditions" are almost invariable "modified historic" conditions since the data for this condition was most readily available.

As used in this report, natural maximum levels and flows are values which are exeeded on the average only once in fifty years. This has been chosen because shoreline processes occur up to the maximum limit of water-level fluctuation; rare events repeated numerous times in past history are therefore, important in shoreline formation. Events rarer than once in fifty years are not well defined quantitatively since the period of record generally is of the order of fifty years. Similarly, water levels and flows would fall below reported minimum values on the average only once in fifty years. Median values would be exceeded on the average every second year.

As used in this report, regulated maximum levels and flows are values which would be exceeded on the average once in twenty years. It is felt that for the fifty year analysis period, this value is the most significant for physical impacts and adjustment processess, as higher values will be experienced only rarely and will, therefore, not be important. Values greater

than the defined maximum will occur possibly two or three times during the next fifty years and will probably not produce obvious lasting effects. This has been observed on Sipiwesk Lake, where the maximum water level since the construction of the Kelsey generating station was considerably higher that the highest apparant shoreline effect. Similarly, regulated water levels and flows would fall below the reported minimum on the average once in twenty years. Median values would be exceeded on the average every second year.

It should be noted that all values are mean monthly values, hence maximum and minimums are values of one month's duration.

5.3 NATURAL STATE PROCESSES

5.3.1 NATURAL STATE PROCESSES FOR SHORELINES - The shorelines, river banks and valleys not affected by artificial controls have achieved a degree of stability since the deglaciation of the region. As in any natural system, susceptible water-land interfaces are subject to continuous erosion and deposition. The shorelines have adjusted to normal process rates in terms of erosion, deposition and vegetation.

Erosion on lake shorelines is a function of the wave energy and materials. The entire Study Area except, the lower reaches of the Churchill and Nelson Rivers, is underlain by igneous and metamorphic rocks. The lower Churchill and Nelson Rivers are underlain by limestones, In both cases the bedrocks are resistant to erosion. These bedrocks are overlain by various thicknesses of overburden primarily in the form of lacustrine clay, silt and fine sand; in some areas the overburden is primarily fluvial sands and gravels. These materials have eroded to form the existing shorelines.

Where wave energy has been sufficient, a common situation is for the overburden to have been eroded until the underlying bedrock has been exposed at the land-water interface thereby forming a stable shoreline (Types 13B and 15 shorelines). Along certain shorelines the bedrock has been covered with little or no overburden, resulting in stable shorelines (Types 11 and 13A). In some cases susceptible shorelines have been stabilized by a build up of boulders, sand or gravel (Type 22 and 27 shorelines). As bedrock headlands emerged, the erosion of the overburden in the intervening embayments has continued until the shoreline has developed a profile adequate to absorb the wave energy without additional erosion occurring. This development has often been accompanied

by the build up of a sand beach. The headlands have assisted in the buildup of the beach by preventing sand generated by the erosion process from moving along the shore and away from the area. The wave energy has become dissipated by the headlands and by drag in the shallow water offshore of the overburden shoreline. These embayment shorelines have then become into a situation of equilibrium between erosion and deposition processes where silt or sand deposits have become built up where a source was available (Type 14b shorelines). Where streams have carried sediments into lakes, deltas have often been built up (Type 24 shorelines).

Some overburden shorelines on lakes have not as yet reached an equilibrium situation. Erosion with slumping of shoreline materials has been occurring under natural conditions (Type 25 shorelines).

Shoreline vegetation is affected by the near-shore topography and the water level fluctuations. Low overburden shorelines subject to periodic inundation tend to establish a willow and alder backshore cover (Type 28 shorelines) because the normal spruce-poplar species cannot survive.

Some organic shorelines are formed when an equibilrium is achieved which allows the shoreline to consist of peat materials (Type 26 shoreline). These shorelines in many cases are still not stable; the peat is slowly eroding and undercutting the overlying vegetation. Some shorelines are founded on organic materials which form flat meadows which may be floating (Type 31 shorelines). These materials are somewhat resistant to wave action due to their bouyancy but tend to erode to smooth concave shorelines.

The processes resulting in the present shorelines have acted through varying lengths of time. Where the original interface was located on a thin overburden, the creation of a bedrock controlled shoreline on sites exposed to wave action would occur fairly quickly. On the other hand, the buildup of a delta deposit by a stream entering a lake would normally take considerable time and the creation of a floating fen would require many hundreds of years. For this reason, the types of shorelines which will be formed within the foreseable future (50 to 100 years) after raising water levels are significantly restricted.

A more detailed discussion of several shorelines follows.

CLASSIFICATION 24 - LOW ALLUVIAL SHORELINE; CLASSIFICATION 28 - LOW WILLOW SHORELINE: The genesis of these two shoreline types is a function of depositional processes and the low nature of the terrain. Type 28 shorelines commonly occur along low lying protected depositional shores while Type 24 can be found where streams enter a lake, thereby forming a delta. Both shoreline processes involve the evolution of an actual physical landform. Plant successional stages follow the deposition of materials. Once the colonization processes begin the vegetation itself modifies the landform. Depositional processes will be accentuated by the vegetation, which in turn promotes further shoreline development.

These low lying shorelines are similar in that they are seasonally flooded by the natural water level fluctuations. In fact, the periodic inundation of these shoreline types is conducive for the perpetuation of the marsh and water tolerant shoreline species. Due to the slope and water regime, the water washed zone is quite wide and is normally colonized by a variety of marsh and shrub vegetation. Emergent vegetation commonly consists of sedges, rushes, and horsetails while a variety of pond weeds form the dominant submerged vegetation.

Marsh vegetation found along these shoreline types is typical of other shorelines but normally not quite as extensive. The species present have definite environmental relationships. They grow under ecological parameters or environmental gradients. These parameters control the species type and the distribution in a given area. Along these shorelines, the species present result from a combination of factors: water depth and fluctuation, the nutrient status, pH and turbulence. The environmental conditions associated with water depth include light penetration, temperature and possibly texture and fertility of the substrate. A change in any one of the above parameters will be detrimental to the marsh species. The plant species found within a community is also a function of competition both interspecific and intraspecific.

Shrubs such as willow and alder typically colonize the zone beyond the marsh on materials which are above the water surface during the latter part of the growing season. The seasonal inundation and subsequent wet soil of the shoreline prevents trees from colonizing the site. Hardwood species such as trembling aspen and balsam poplar have a higher tolerance to saturated soil conditions than white spruce, and therefore, are normally found colonizing the beach materials back of the shrubs. Historical high water levels have little effect on shrub survival as one year of continuous flooding will not result in the death of these water tolerant species. Shrub growth will still continue during this high water period. The shrub stand is usually of uniform height and density and devoid of an understory.

CLASSIFICATION 31 - FEN SHORELINE: The shoreline classification system describes one type of fen typical of the Outlet Lakes area. However, there are many types of fens. In Reference 10, fens are defined as being either: horizontal, floating, patterned, sloping, spring or collapse scar. Of these, only the spring, horizontal and floating fens were recognized to form shorelines within the Study Area. All other types are typical of backshore areas. Type 31 fen described in the shoreline classification system is a horizontal fen. Generally, horizontal fens are much more extensive than floating fens.

A fen may be defined as a low organic shoreline composed primarily of Carex spp. (sedge) and gramineae (grasses). The vegetation may be either rooted into the substrate or floating. As the fen matures (there is an increase in the depth of peat), it will be colonized by a variety of shrubs and sometimes conifers, as shown in the following diagrams.

Fens are unique plant communities in that they maintain a certain form or sere (Figure 29). Successional processes in most communities result in the formation of a treed cover but this is not the case with fens because of their location. Typically fens exist along open sheltered bodies of water where they receive an in-flow of nutrients and oxygenated water and are subjected to various changing seasonal water levels.

All three factors are responsible for the perpetuation of the fen. The nutrients and oxygen are necessary for the activity of microbial agents which prevent peat accumulation by breaking down the plant fibers. Therefore, the successional plant processes are slowed down. In fact, the sedges and grasses will remain the dominant vegetation when the decomposition of peat materials is equal to the production of peat materials.

Floating fens are undoubtedly the most dynamic shorelines in that they adjust to the seasonal water level fluctuations. The consolidated nature of the sedge provides the matt with a certain degree of buoyancy. Although the bulk of the matt is below the water surface, the matts do exhibit vertical mobility. This floatation becomes very important as the total species complement of the fen is governed by the water level fluctuation. In a normal water basin, the spring water levels are higher than the mean open water season levels while the late summer levels are lower. This high spring level undoutedly has a retarding effect on the fen backshore colonization processes. The majority of fens are devoid of trees. The water table is too high relative to the fen surface for trees to survive.

Figure 30 illustrates the effect of sedge matt mobility on the colonization processes. Clearly all tree successional processes on the fen are retarded due to the seasonal backshore water logging phenomenon. An example of fen perpetuation is on the Waddie River complex of Southern Indian Lake. Here, the normal yearly fluctuation is in the order of three feet while the historical fluctuation is in the order of eight feet. This rising and lowering of water levels has enabled this fen to remain in an early successional stage even though it may have been formed many years ago (Photograph 35).

PHOTOGRAPH 35 - Fen shoreline at Waddie River Outlet on Southern Indian Lake. Note the sharp demarkation between the spruce forest and the sedge matt. The fen area is heavily populated with shrubs tolerant of the seasonal flooding.

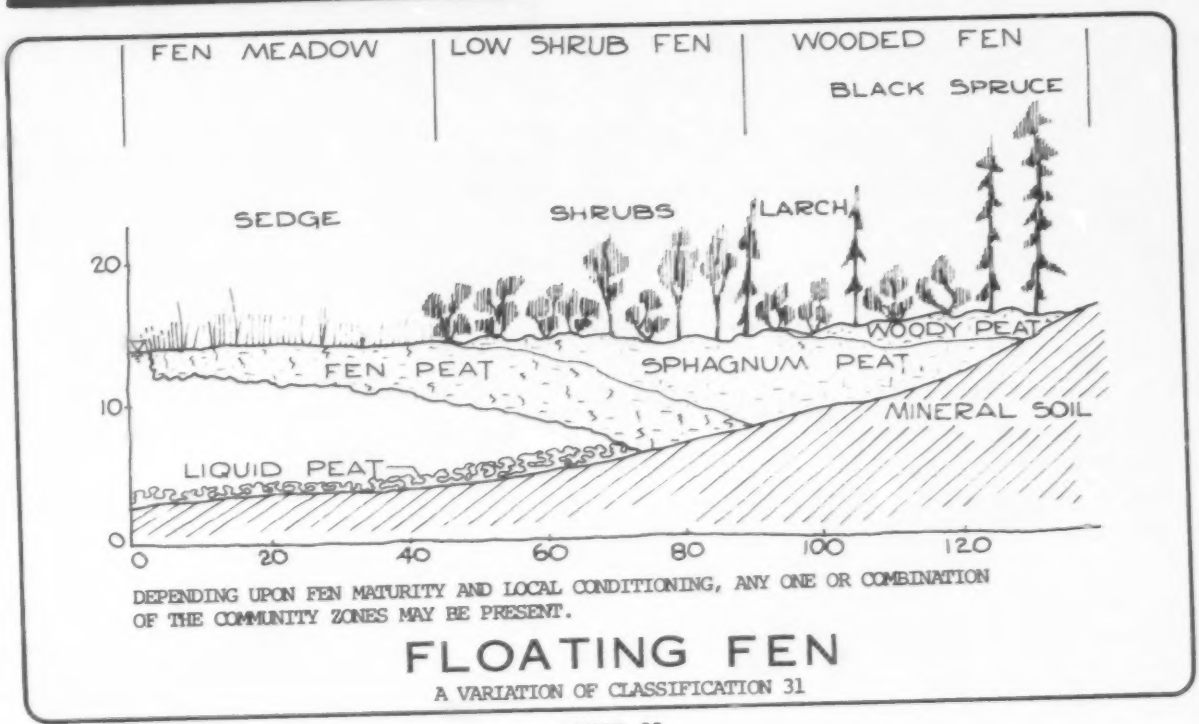


FIGURE 29

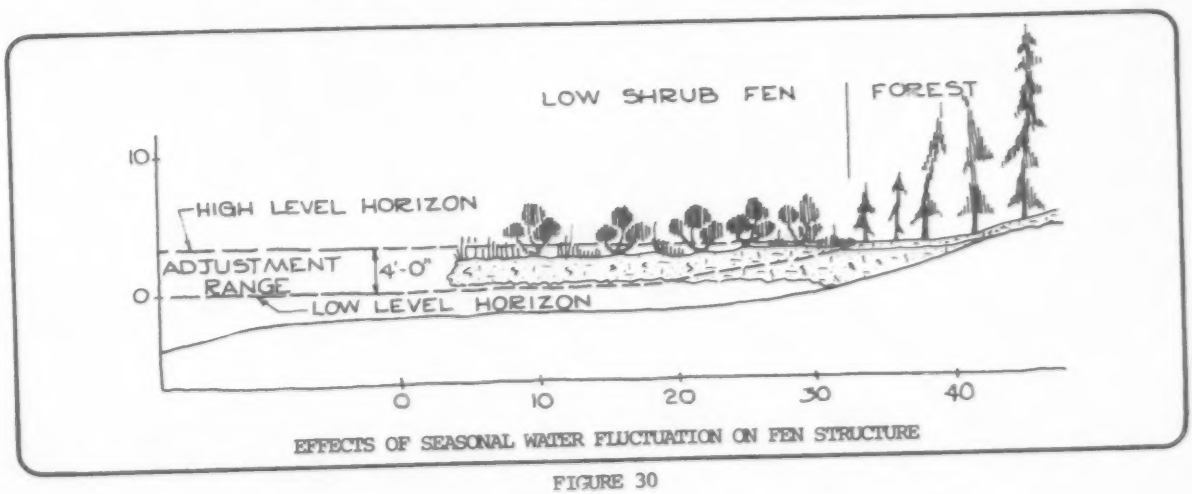


FIGURE 30

5.3.2 NATURAL STATE PROCESSES FOR SHORELINE AREAS - Only the "Organic Terrain in Valleys" classification requires mention here. The bog and fen portions of this shoreline area react to increased water levels in the manner described in the section "Natural State Processes for Inundated Terrain - Sedge Communities," Section 5.3.3.

5.3.3 NATURAL STATE PROCESSES FOR INUNDATED TERRAIN - Of all the inundated terrain units, only the sedge communities warrant a discussion. The natural state processes of other terrain units for the purposes of this report have been adequately covered in "Classification System for Inundated Terrain", Section 5.2.3.

CLASSIFICATION - SEDGE COMMUNITIES: Northern Manitoba is endowed with a variety of sedge communities, all of which are in various stages of development. Bogs and fens are peat lands characterized by the poorly and moderately decomposed peat of variable thickness. The peat itself may be defined as the remains of plants and animals which, because of water logged conditions of the soil and lack of oxygen, have failed to fully decompose. Under such conditions the peat accumulates, compressing the lower layers.

The fundamental distinction between a bog and a fen is that a bog has a closed drainage system while a fen has an open drainage system. At some early stage in its development a bog may have many of the plant species common to a fen. The divergence of plant species composition becomes marked as a bog evolves to a mature state.

Fens are typically located on open water systems bounded on one side by a lake or river shoreline (Photograph 36). The rooting zone is subject to washing with silt and/or mineral soil water. Such nutrient rich sites are referred to as minerotrophic. Generally the peat materials are neutral to basic. The availability of nutrients is reflected in the high productivity and diversity of the fen vegetation. The dominant vegetation consists of sedge, often with a low shrub cover. The maturer sites may be sparsely colonized by spruce and larch.

In Reference 10, the various fen types in Northern Manitoba were identified as being either: horizontal, floating patterned, sloping, spring, or collapse scar. Of these, only the patterned, sloping and collapsed scars were identi-

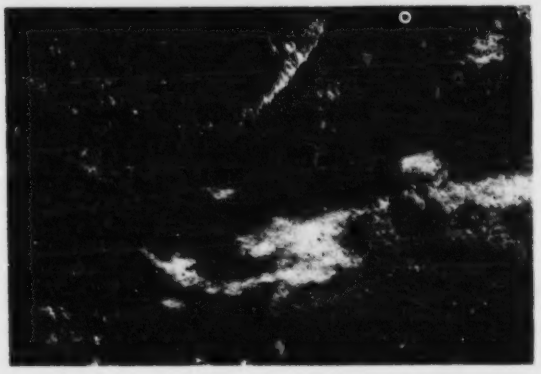
fied as existing in the backshore of the Study Area. The type present in any one area is a function of the local topography, hydrology and water movement pattern.

PHOTOGRAPH 36 - A fen community along the Waddie River outlet to Southern Indian Lake. The sedge is heavily colonized by shrubs. Note the presence of tamarack in the foreground, a pioneer colonizer of sedge communities.

Bogs are peat covered or peat filled areas generally lying within a high water table. In the mature state they have a lower water table than the typical fen. They are formed in closed drainage systems in a nutrient starved environment. In general such sites are referred to as ombrotrophic. The major nutrient source and water source is precipitation. The low nutrient status of a bog results in low primary productivity and species restricted composition. The dominant vegetation is a Sphagnum moss with a variety of shrubs - Ericacae family, willow, alders, and trees - larch and black spruce. The Sphagnum spp. are the primary peat producers.

There are a variety of bog landforms within the study area. In Reference 10, bogs are divided into two types, ombrotrophic and transitional.

Ombrotrophic or raised bogs are described as palsas, peat plateaus and bog plateaus. Palsas and peat plateaus are elevated due to the ice content in the peat. Bog plateaus are raised due to the accumulation of peat materials and are typical of non-permafrosted zones. Transitional bogs (Photograph 37) occupy transitional areas receiving some nutrient rich waters from mineral soil. Sphagnum is the dominant peat producer; however, a sedge peat may form the underlying material. Transitional bogs are described as being either a flat bog, a bowl bog or a blanket bog. The bog types are a function of local climate, topography, hydrology and water movement patterns.



PHOTOGRAPH 37 - A typical bog community in Northern Manitoba. There is a distinct gradation of species from the open water to the mature forest. Note the diminishing size of the colonizing spruce as the soil conditions are wetter.

Within the northern Manitoba landscape, the diversity of sedge communities is conspicuous. These peatlands exibit a wide range of developmental phases. In both bogs and fens the typical evolutionary development is considered to begin with a young species-diverse community culminating in a species restricted climax community. The successional stages have sometimes been considered to be unidirectional and

final. However, any phase of the peatland development should not be regarded as being merely a step in the orderly development of vegetation toward a mesophytic or climax community. The fact is that landforms are the net result of an interplay of a multitude of physical and biological events that have occured over time. As a consequence a sedge community may in some phases be either regressional or successional. New sedge communities are constantly being created, expecially in collapse scars in discontinous permafrost zones. The peatland community is the product of several factors: topography, moisture regime, groundwater chemistry and vegetation. The interrelationships of these factors shall be discussed to show how they control the distribution of species and communities. Certain phenomena will retard successional processes while others will promote them.

Before the various factors and their interrelationships are discussed, the normal successional processes of a bog should be mentioned. The typical text book description of bog succession is only a model and not a comprehensive explanation of any bog type development (Figure 31). Typically, a bog is formed in a depression, a lake or pond that is poorly drained. The area is continuously staturated with water. Usually the only source of water is from precipitation. Initially the shallow open body of water is inhabited by aquatic plants - submerged and floating while the bog periphery may support emergent vegetation such as sedges. With the gradual accumulation of organic matter, the water volume is reduced. The sedges may be rooted in the substrate or form a floating matt. Slowly the matt extends out from the periphery colonizing the open water surface. Once a consolidated sedge matt is formed the conditions are suitable for the establishment of other species. Bog cotton and mosses, primarily Sphagnum, will colonize the matts along with a variety of shrubs of the Ericaceae family. After a Sphagnum mantel has been formed, larch and black spruce will colonize the area. Upon establishment of the dominant ground flora, Sphagnum becomes the major peat producer, building up peat at a faster rate than the preceeding vegetation. Peat accumulation rates of 1.9 inches per century (Reference 11) are typical of the peatlands of northern Manitoba. This step-by-step filling-in process is due to the poor decomposition rates within the bog waters. The acidic conditions, low oxygen availability and low nutrient supply are not conducive to decomposing agents, bacteria and fungi. Therefore, organic materials accumulate. With the peat accumulation conditions change and vegetation intolerant of the new nutrient, pH and moisture conditions give way to more tolerant subsequent vegetation.

In most plant communities, the dominant flora creates conditions which will not allow for the self perpetuation of its own species. This is the reason for the change in plant associations as a community matures. Once the Sphagnum moss is established on a sedge matt, the conditions change considerably. In this case, the Sphagnum enhances the perpetuation of its own kind elimating other species by altering the pH of the substrate, creating acidic conditions. The Sphagnum species have different tolerances to pH which allows for the establishment of one species leading to the succession of another.

The change from a sedge to Sphagnum peat may also effect hydrological and thermal properties. Accumulating Sphagnum may act as a barrier cutting off water

flows. The morphology of the Sphagnum itself becomes important as the leaves typically have a high water retaining capacity, thereby allowing the moss to control its own moisture regime. This aspect may result in inadequate aeration for tree roots. Also, the cooler temperatures of the saturated peat may be a deterrent to species diversity.

This whole peat accumulation process and establishment of floral communities or zones may be referred to as occurring in stages: pioneer, settlement and subclimax (Figure 31). The pioneer stage is the phase during which the sedge matt colonizes the mineral soil or water surface. The settlement phase culminates upon the definite establishment of a continuous Sphagnum sod, while the subclimax stage is achieved with the invasion of trees. A climax stage is realized when the organic material has sufficiently built up to support a forested community. Even during the climax stage the species composition will be changing due to the conditions created by the conifers. All shade-intolerant flora can be expected to be phased out. This will exclude the majority of the dominants found in the consolidated phase.

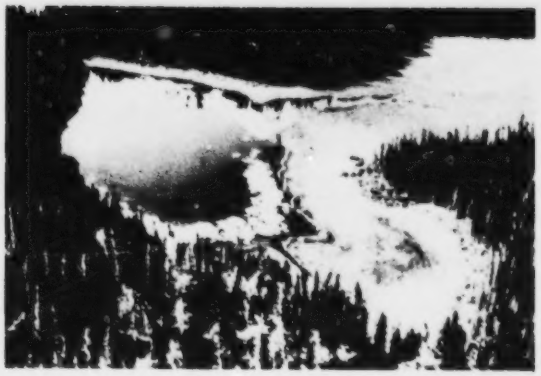
At some stages of their development, fens and bogs may seem to be very similar. Some authors choose to regard a fen as a phase of a bog formation. This theory, however, is misleading and an oversimplification. Although in the natural state, the major floral associations of bogs and fens differ, in intermediate stages they exhibit common characteristics, primarily the sedge vegetation. An example of a species composition of both fens and bogs and their related soil conditions (pH) is shown in Table 5.

The critical factors resulting in the type of sedge community to be formed are groundwater chemistry and the hydrology. Sites with a source of mineral influenced water are invariably fens.

The water movements and influence of minerotrophic water will increase the pioneer span of the fen as the avialable oxygen and nutrient status is conducive for microbial activity. This will promote the decay of organic matter thereby reducing peat accumulation and ultimately slowing successional processes down. In the closed bog environment (Photograph 38) even their low protected nature becomes significant as the reduction of wind action will check the aeration of open water and favour anerobic conditions. Bog water retards microbial activity preventing recycling of nutrients and allowing the establishment of Sphagnum, all of which will facilitate peat accumulation. The fluctuation of water levels and an open drainage system becomes very crucial in the development and the retention of a sere stage in certain fens.

Bogs are also subjected to water level fluctuation, but they are minimal, low enough so as not to effect the successional processes. In an extreme case a bog may fluctuate about two feet.

In the vast majority of situations, bogs and fens can be recognized as two different communities.



PHOTOGRAPH 38 - A bowl bog in the early successional stage.

TABLE 5

THE ABUNDANCE OF EIGHTEEN SPECIES OF PEATLAND PLANTS IN RELATION TO THE NUTRIENT STATUS OF DIFFERENT COMMUNITIES.

Type of Wetland	Bog	Poor Fen	Poor-Mod. Fen	Mod.-Rich Fen	Rich Fen	Calc. Fen
Acidity	ext. acid	very acid	acid	sl. acid	neutral	alkaline
As pH	3.2-4.2	3.8-5.0	4.5-5.6	5.5-6.5	6.0-7.6	6.8-8.3
Calcium levels	very low	low	moderate	moderate -high	high	very high
Marsh fern (Dryopteris thelypteris)			+	+++	++	+
Arrow grass (Triglochin maritima)				+	++	+++
Scheuchzeria (Scheuchzeria palustris)	+++	+				
Three leaved Smilacina (Smilacina trifolia)			+	++	+	
Fen cotton grass (Eriophorum spissum)			+	+++	++	
Hare's tail (Eriophorum spissum)	+++	++	+			
White beak sedge (Rhynchospora alba)	++	+++	+			
Bog sedge (Carex limosa)	+++	++	+			
Few-seeded sedge (Carex oligosperma)	+	+++	+			
Yellow sedge (Carex flava)				+	++	+++
Lady's slipper (Cypripedium calceolus var. parviflorum)				+	++	+++
Pitcher plant (Sarracenia purpurea)	++	+++	+	+	++	+++
Marsh cinquefoil (Potentilla palustris)		+	+	+++	++	
Shrubby cinquefoil (Potentilla fruticosa)				+	++	+++
Dewberry (Rubus chamaemorus)	+++	+				
Bog bean (Menyanthes trifoliata)		+	++	++		
Labrador tea (Ledum groenlandicum)	+++	++	+	+		
Bog Rosemary (Andromeda glaucophylla)	++	+++	+			

Key: + occasional, ++ frequent, +++ abundant (Mod. = moderately rich, Calc. = calcareous).

* *Table taken from Ontario Naturalists Vol. 13, No. 3, 1973.*

BOG ECOSYSTEM

SUCCESSIONAL PROCESSES OF A BOWL BOG

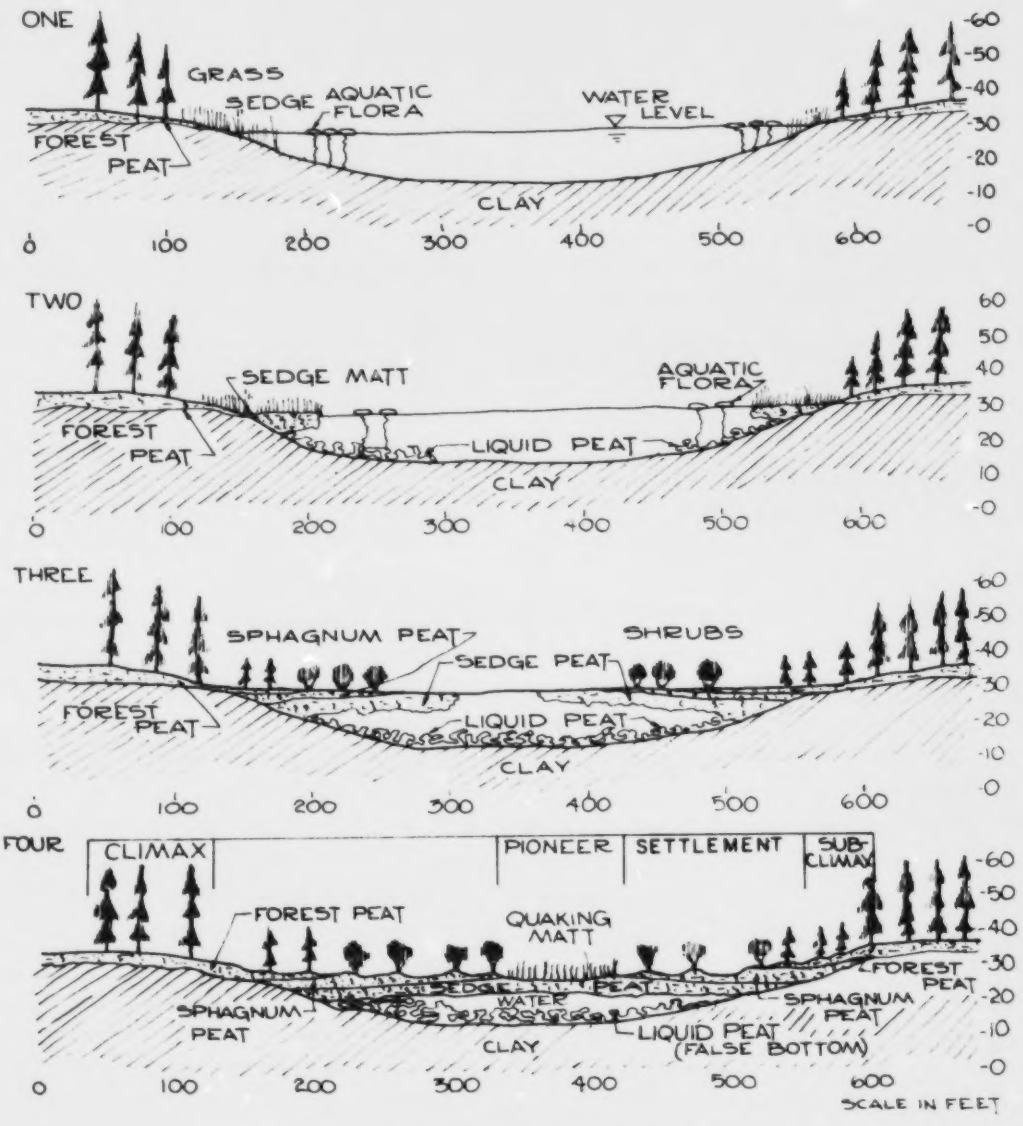


FIGURE 31

5.3.4 NATURAL STATE PROCESSES FOR RIVER CHANNELS - The river channels in the Study Area are the product of several thousand years of activity since the last glaciers disappeared from the area. River channels have eroded through glacial lake deposits and limestones to the point where the channels are controlled by vertical bedrock in almost all locations. Bedrock shorelines exert a minor influence on the horizontal configuration in many areas by confining or directing stream flow and thereby are instrumental in river processes in the present stream. Reaches not influenced by bedrock are not common, but occur in the following locations: in the Burntwood system between Thompson and the upper end of Birch Tree Lake, in the upper portion of the Rat River, in a short section of the Churchill River below Billiard Lake, and in the lowest reaches of the Nelson and Churchill Rivers.

The major physical shoreline process active on the present channel shorelines is erosion and related sediment transport. Sediment in the channel comes from three main sources - tributary streams, "sheet" erosion of river banks and adjacent areas by local runoff, and channel erosion of the bed and banks (especially significant during high flow periods).

Sediment in motion moves either in the main body of flow (suspended sediment) or on the stream bed (bed load sediment) depending on the particle sizes and the hydraulic forces acting on them. Larger particle sizes, specifically sands and gravels, move on or near the river bed if the force (or bed shear stress) is large enough. These sediments are readily deposited in calmer areas in channel enlargements or lakes. Clays are more susceptible to erosion and go into suspension readily. Once in motion these particles do not readily settle out of suspension due to their small size. For example, tests on Burntwood River bank material indicate settling times of 3 to 44 days (Reference 12), for ten feet (with no particle flocculation). Retention times in the Burntwood River lakes are generally shorter than this, so much material is carried in suspension through the lakes.

River erosion takes place in two directions - vertically downward and laterally. Rivers in the study area have eroded downward to the point where they are largely controlled by bedrock. This type of erosion is therefore minimal in most places under the present flow regime, and erosional and depositional processes, on the river bed, balance over time. Erosion of river banks and lateral channel movement is apparent at several locations, especially during high flows. Slumping clay banks (Type 25 shorelines) along sections of the lower Burntwood River, especially at curves in the river are examples of this process. Reaches of the Burntwood River which have thinner overburden are controlled laterally largely by bedrock shorelines (Type 13) and display less meandering and slumping.

In the Study Area, permafrost is an important factor in bank instability. Permafrost occurs in scattered locations on several of the shoreline types. Melting of this permafrost reduces the strength of the bank material and is at least partly responsible for the instability of Type 25 shorelines. In addition to permafrost, seasonal freezing and thawing of the banks in this northern area reduces the material strength and contributes to accelerated erosion.

The erosional processes are important in establishing the form of the river channel. Larger discharges result in larger channels. The present channel therefore represents a long term balance between erosion during high flows and deposition in low flow periods.

The type of sediment carried in the stream is also important. Streams which carry their load chiefly as suspended sediment generally require a larger depth-to-width ratio than those with a high bed load. The Burntwood River, for example, is deep throughout most of its length. This is representative of a low bed load, which would be expected from the predominance of small grain-size materials (silts and clay) in bank samples.

Wave action must also be considered as a shoreline process. In narrow, confined rivers, the current is the major adjusting force. In the case of a lake, the current is minimal and wave action dominates. In wider areas of river channels, both mechanisms come into play, and either one or the other may be more important.

In addition to erosion by currents, ice abrasion is important along rivers in these northern areas. Great thicknesses of ice can be generated during the winter by formation of ice jams down stream from faster-flowing sections. This results in higher water levels and shoreline scour high above the open-water level. Even without ice jams floating ice can result in increased erosion during spring breakup.

The various forces outlined above largely determine the type of shoreline at the present land-water interface, depending on local geologic features (depth of overburden, bedrock outcrops, etc.) Type 13B shorelines for example, are the result of erosion of overburden from bedrock outcrops where scouring is great. Types 14 and 15 occur in areas where erosion is less (slower current, and sheltered locations). Types 11, 12 and 13A occur due to bedrock control with no overburden erosion. Stable clay banks, Type 23, represent a balance of forces, for areas where bank erosion is too slow to produce visible effects. Type 24 represents deposition in calmer water of some of the suspended sediment. Type 28 shorelines occur in rivers in low backshore areas, generally along wide stretches of the river, and are therefore similar in genesis and physical features to the corresponding lake shoreline. At least one shoreline type (Type 21, ice scoured bank) is peculiar to the river case, and is the result of ice formation and damming in the river.

Vegetation along the river shoreline is influenced by the erosion and depositon processes, the resulting shoreline configuration, and water level fluctuations. Willows, for example, are established in areas of occasional flooding, often in depositional sites. Likewise, sedges, grasses, and small shrubs are the only vegetation types that can be established on shorelines that are seasonally scoured by ice (Type 21).

Larger species become established along other shoreline types, depending on local drainage, water level fluctuation and shoreline retreat by erosion.

5.4 IMPACT PROCESS STATEMENTS

The general impact processes on lake and river shorelines will be discussed in this section, the site specific impact statements will follow in the subsequent chapter. In discussing the impact processes, the time at which a particular sequence of events is viewed is extremely important. Some impacted shorelines will stabilize relatively quickly while other will not stabilize within the foreseeable future. The time taken to achieve a stable shoreline depends upon many factors - exposure to wave and/or current energy, ice action, material type, thickness of various materials, offshore water depth, onshore topography, offshore and onshore vegetation, and water level fluctuations. Shoreline impact will be discussed for three time intervals: and Initial Impact, and Adjustment Phase, and a Fifty-Year Time Frame.

- Initial Impact: This is the period during which the majority of vegetation will be killed and may be considered to include the first two years after the water level rise.

- Adjustment Phase: This is the time period during which the main adjustments will be made on the majority of the impacted shorelines. Most adjustments will be made during the period of five to thirty years after flooding.

- Fifty-Year Time Frame: This is the time at which most shoreline processes have reached a condition of near equilibrium or stability. This time frame was chosen as it was felt that predictions could be made with some confidence within the fifty years after impact. Also, this time frame was assumed to be important to other study components.

Under each time interval three cases of water level rise were considered: restricted flooding, low level flooding and high level flooding. These three flooding levels were chosen when discussing impact as the process on a shoreline will vary to some degree depending upon the total water level rise.

- Restricted Flooding: This is a water level rise in the order of two feet which would lead to very little shoreline inundation except on Type 24, 28, 26 and possibly 31 shorelines. On most shorelines, the new water line will be contained within the water washed zone. The major impact here is one of accelerated shoreline erosion. Back shore water looging generally becomes significant only at higher levels of flooding.

- Low Level Flooding: Low level flooding pertains to water level rise in the order of ten feet. In most cases this will lead to a relatively narrow offshore zone of dead trees. More trees will be inundated along stream valleys and in embayments. The accelerated erosional processes are quite noticeable under such flooding levels.

- High Level Flooding: This is a water level rise in the order of twenty to fifty feet which in most cases will result in a considerable amount of terrain being inundated. Erosional processes will be similar to the low level flooding situation.

In this section, a general impact statement will be made for each of the 15 Shoreline Types, the four Shoreline Areas and the six Inundated Terrain Units. Some of the Shoreline Types occur in areas which will undergo a lowering of water level. The Type 21 Shoreline in particular will be discussed from that point of view in this section. The effects of lower water levels on other shorelines will be discussed in the site specific sections.

The impact process statements are made under the assumption that the controlled lakes and channels will have a relatively constant water level (plus or minus two feet). Any deviation from this will be dealt with under the site specific discussions. Special problems such as ice jamming will also be dealth with in the site specific discussion.

5.4.1 IMPACT PROCESS STATEMENTS FOR SHORELINES -

CLASSIFICATION 11 - STEEP BEDROCK SHORELINE:

Impact Sensitivity - This shoreline will not suffer major adverse effects under any flooding conditions. As the steep bedrock slope contains little or no overburden, erosion is negligible and only a few trees will be flooded. The lack of overburden, and consequently sparce plant cover, is primarily a function of the bedrock slope. The few trees found growing on the rock face are usually rooted into the rock itself. Rate of removal of inundated trees is a function of exposure. Headlands will be cleared before protected shorelines. On lake shores, wave energy will be the chief tree removing agent, while along river channels, the currents are the main forces. Scouring action of ice on flooded trees may be of equal importance on both lakes and channels.

Initial Impact -

Restricted Flooding: All available soil will be washed off the slope. Only the vegetation within the water washed zone will be affected; shrubs constitute the majority of this cover.

Low and High Level Flooding: In both cases all available soil will be washed off the rock face. The width of inundated cover will depend on the slope and the extent of flooding. The majority of trees will likely remain in place during this period. Trees that are growing on a thin soil cover and not wedged into the rock will probably be removed immediately.

Adjustment Phase -

Restricted Flooding: During this phase, the inundated shrubs and trees will be removed by the erosive agents.

Low and High Level Flooding: The majority of the inundated trees will be removed during the early years of the adjustment phase. Due to the sparseness of the inundated trees, the slope, and the continual erosive action, offshore detritus or onshore driftwood will be negligible.

PHOTOGRAPH 39 - A flooded Steep Bedrock Shoreline on Russell Lake, flooded 1952. Water level rise ten feet.

Along the Steep Bedrock Shoreline there is no indication of a water level increment. Note the marked effect of sparce soil and low moisture on tree growth along the bedrock surface (Photograph 39). Wind action and currents are the forces responsible for moving the floating sedge islands within the channel. Of significance is the fact that the floating sedge matts are still intact and supporting living vegetation 21 years after flooding.

Fifty-Year Time Frame - All Level of Flooding: (Figure 32). Within a twenty-year period, the majority of the sites will show little indication of having been inundated for all levels of flooding.

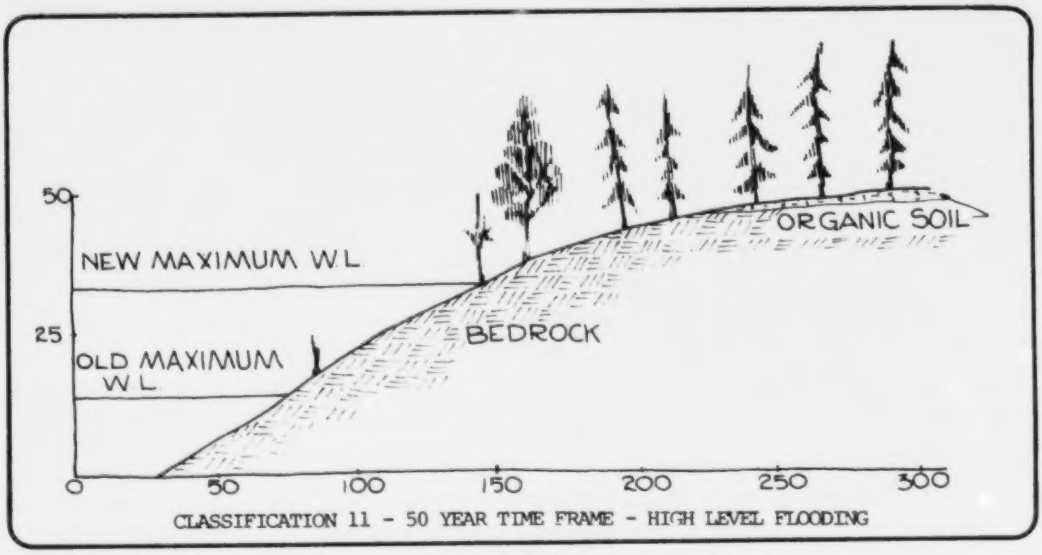


FIGURE 32

CLASSIFICATION 12 - VERTICAL BEDROCK SHORELINE:

Impact Sensitivity - It is anticipated that regulated water levels will remain within the exposed bedrock portion of the shoreline for all Type 12 shorelines in the Study Area (Figure 33). Due to the lack of soil and vegetation, this shoreline type will be least affected by increased discharges and levels. Erosion of the channel bed and banks will be increased, but this rate is too slow in human terms to be noticed. Impact on this shoreline can, therefore, be considered non-existant. Reduction in discharge will likewise result in negligible impacts.

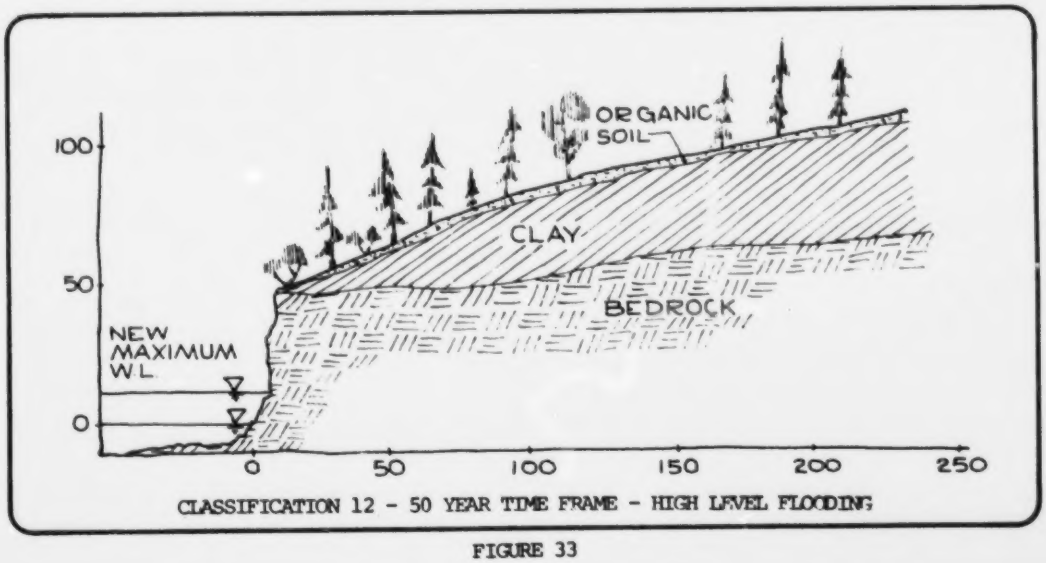


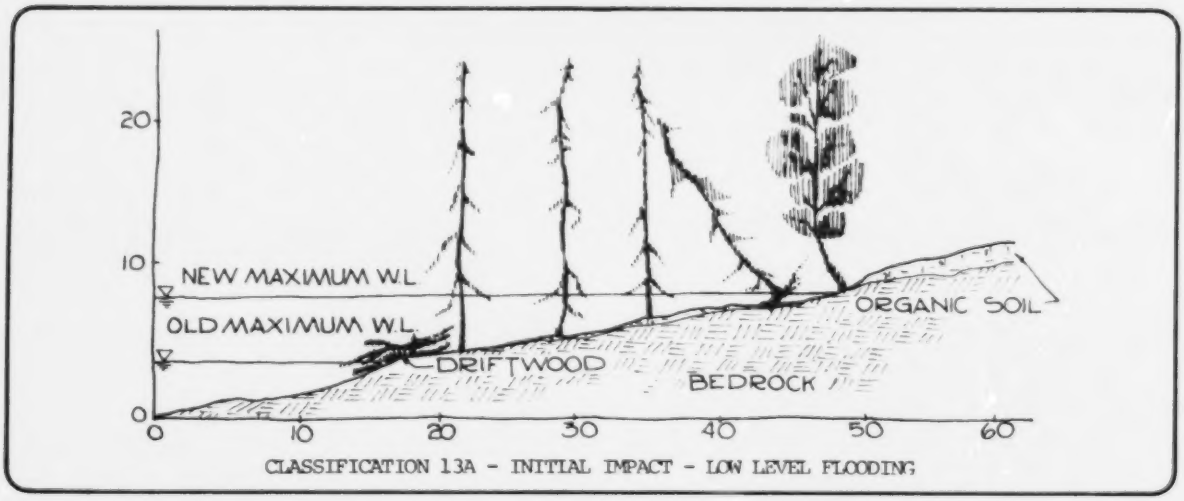
FIGURE 33

CLASSIFICATION 13A - LOW BEDROCK SHORELINE WITH SHALLOW BACKSHORE OVERBURDEN:
Impact Sensitivity - In all three flooding situations, the shorelines exposed to greatest erosion forces will be the first to reach a natural state condition. The greatest impact on these shorelines will be the large amount of wood accumulating along the new shorelines.

Initial Impact -
Restricted and Low-Level Flooding: These two flooding situations will be dealt with together as both shorelines will be effected in a similar manner.

The erosion forces of current, ice movement, and wave energy will remove the organic soil layer in the new water-washed zone. Since bedrock is close to the surface, the shoreline interface will not retreat significantly beyond the initial point of impact (Figure 34). Trees growing in the thin soil cover will be uprooted and will accumulate along the shoreline.

Trees wedged within the bedrock substrate, may not be knocked down during the initial stage. In certain cases ice movement will be a significant factor in removing trees. The width of the flooded area is a function of the slope and depth of flooding. This fringe of flooded trees is generally less than 100 feet wide.



CLASSIFICATION 13A - INITIAL IMPACT - LOW LEVEL FLOODING

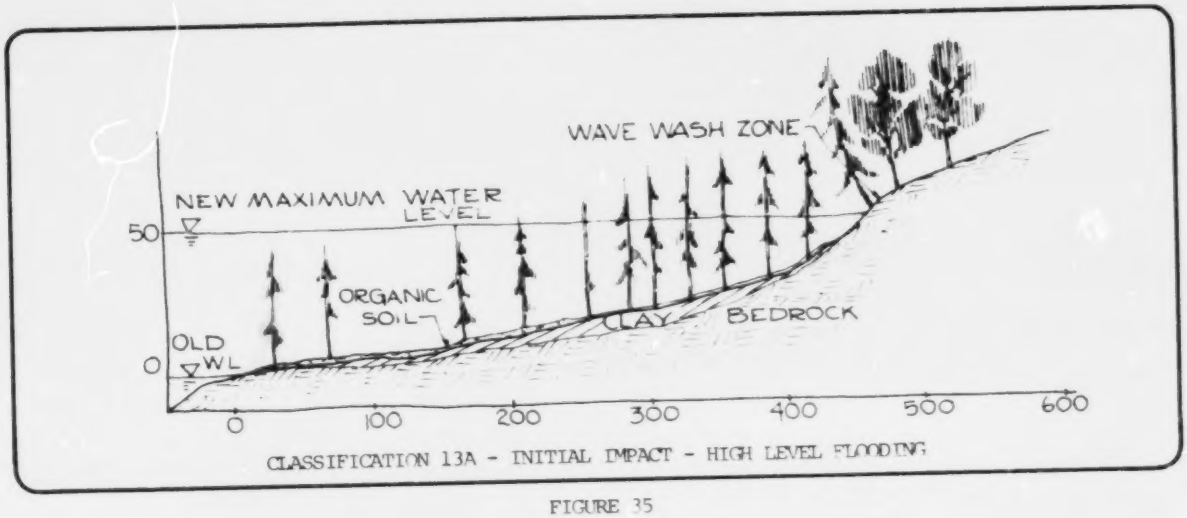
FIGURE 34

High-Level Flooding: In this situation, the area to be flooded typically contains a greater depth of mineral soil overburden and denser forest (Figure 35).

Initially all erosive forces will have less effect on the new shoreline due to the influence of the flooded standing trees. The soil at the new water line may not be removed, nor may the flooded trees be knocked down. The denser tree growth will be on the moist overburden acreas. Standing trees are important as they will inhibit erosion by dissipating the wave energy before it can reach the shoreline. Ice movement may be an important agent in removing the flooded trees, possible more so than wave action.

From our observations it appears that trees growing on till or on bedrock outcrops will stand longer after flooding than trees growing on organic soil.

The fringe of offshore dead trees will probably be wider than 100 feet. This is a function of the slope.



CLASSIFICATION 13A - INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 35

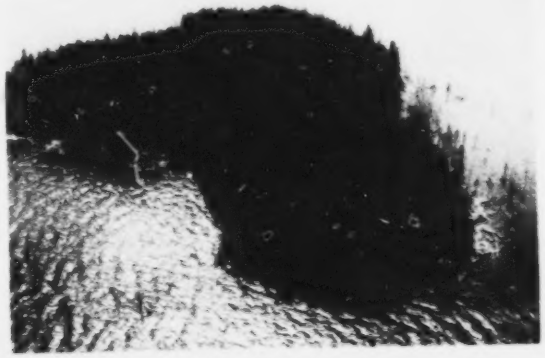
Adjustment Phase -

Restricted and Low-Level Flooding: During this period, all soil will have been removed in the water-washed zone. On exposed sites the majority of the standing trees will have been knocked down and removed. These processes could be complete in ten years. The accumulation of driftwood is primarily a function of the shoreline configuration. Headlands tend to be cleared while concave shorelines retain and accumulate the driftwood from adjacent promontories. This is illustrated in Photograph 40. On less exposed sites the felling processes may not be completed for twenty years.

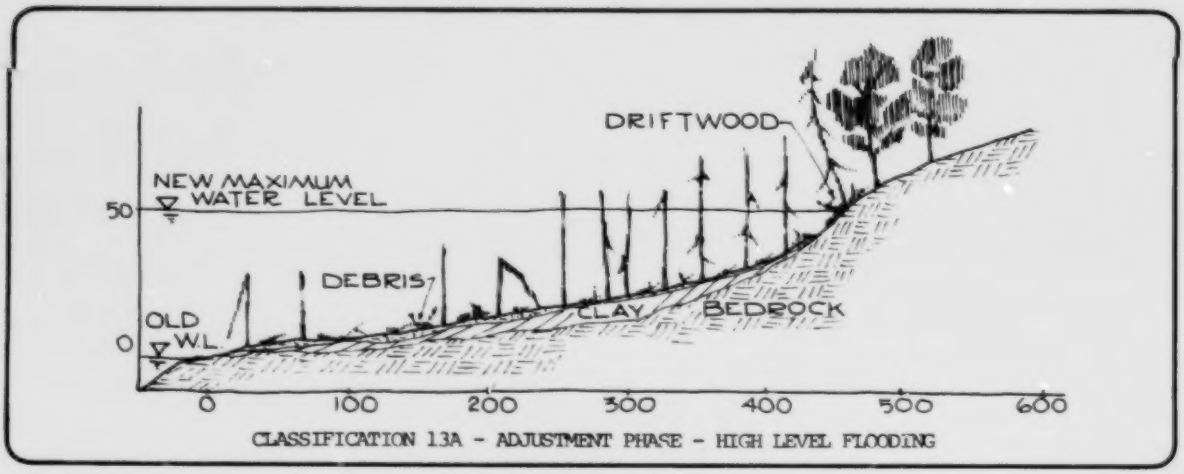
PHOTOGRAPH 40 - Type 13A shoreline on Russell Lake, flooded 1952. Water level rise - ten feet.

High-Level Flooding: The soils will have been removed in the water washed zone, but a significant amount of offshore standing trees may be present (Figure 36).

Along protected shorelines, the trees may be upright 25 years after flooding and remain so for another 20 years (Photograph 41). This is especially true on the lee side of islands.



PHOTOGRAPH 41 - Type 13A shoreline on the Laurie River, flooded 1952. Water level rise less than 52 feet. Note the extent of standing timber along sheltered shorelines.



CLASSIFICATION 13A - ADJUSTMENT PHASE - HIGH LEVEL FLOODING

FIGURE 36

Fifty-Year Time Frame -

In All Flooding Situations: Bare rock will be exposed to the highest water-washed level in all flooding situations. Trees wedged into the rock may still be standing, but will be broken off just above the maximum water level line. This breaking point is a result of the rotting of the moist emergent wood.

Hardwood trees will rot much sooner than the conifers which are not as susceptible to decomposing organisms. Areas subjected to high level flooding will contain the highest concentration of driftwood and detritus. This severely hampers any type of movement along the shoreline and inhibits shoreline access by boat. This shoreline mobility is very important for some local fauna. For example, mammals such as foxes rely quite heavily on crayfish for part of their summer diet. This driftwood and detritus will inhibit this summer food obtaining activity. The Type 13 shorelines are ideal crayfish habitat.

On the majority of impacted shorelines, the width of the exposed wave-washed rock will be reduced as the extent of the water-washed zone is a function of the water level fluctuation (Photograph 42 and 43). In a normal lake situation, a wide range of water level results in a substantial wave-washed zone, while in a reservoir situation the fluctuations are normally reduced. Therefore, the zone in the latter case is not as great. This is assuming that all the slopes are the same. Consequently, there will be less shrubery inhabiting the reservoir shoreline.

PHOTOGRAPH 42 - Type 13A shoreline, Southern Indian Lake. The water-washed zone supports a variety of shrubs, grasses and annual plants.

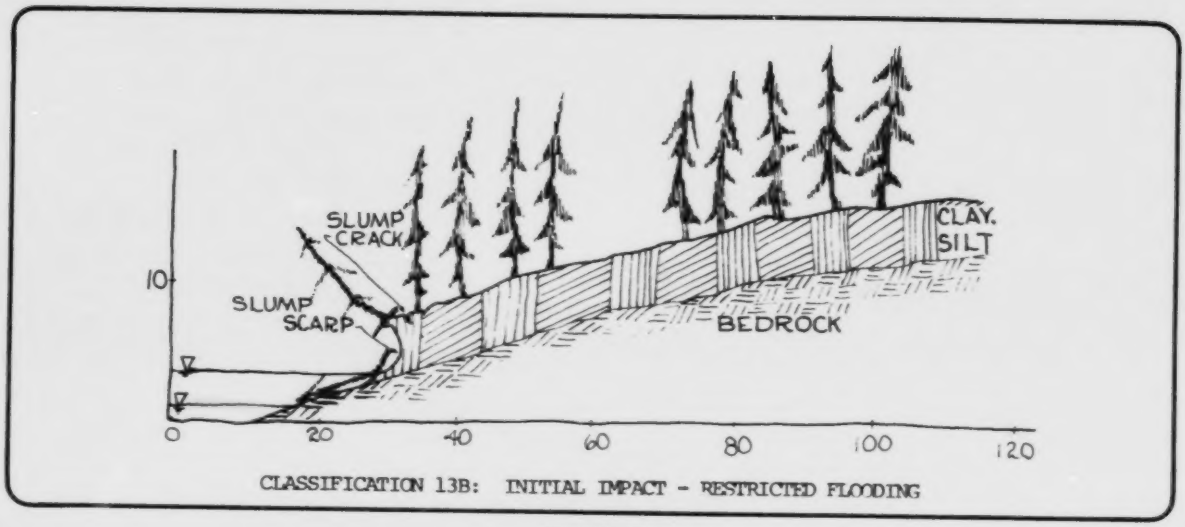
PHOTOGRAPH 43 - Lac Seul, flooded 1929. Water level rise - ten feet. The water-washed zone is reduced and so is the shrub growth.

CLASSIFICATION 13B - LOW BEDROCK SHORELINE WITH DEEP BACKSHORE OVERBURDEN:
Impact Sensitivity - The major impact consideration along this shoreline is the depth of erodible overburden. When materials are eroded, the undercut trees will fall and accumulate on shorelines obstructing wave energy from eroding bank materials. The fallen trees will severely hamper mobility along the shoreline and access by boat. In any flooding situation, the extent of the horizontal retreat of the bank will depend upon the depth of flooding, the exposure, the material depth and composition, and the slope. Sites exposed to the severest erosional processes can be expected to achieve a stable shoreline within the shortest time period.

Permafrosted overburden will have its own effect on shoreline evolutionary processes. The melting of permafrost will undoubtedly create unstable conditions at the new waterline, allowing the overburden to be eroded away faster, thereby reaching bedrock sooner, but the bank and backshore area may take longer to reach an equilibrium state.

Initial Impact-
Restricted Flooding: As the water level is rising, the overburden bank materials will be eroding resulting in the undercutting of the tree cover (Figure 37). All undercut vegetation will likely accumulate along the shoreline. Wave action is expected to be a stronger eroding force than either current or ice action.

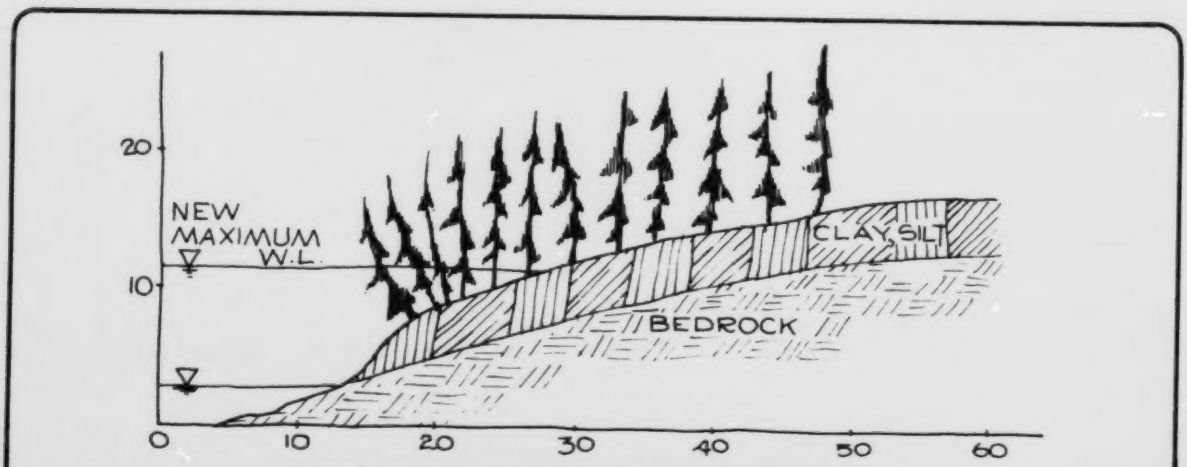
The increment is so slight that the bedrock will always be exposed at the water line.



CLASSIFICATION 13B: INITIAL IMPACT - RESTRICTED FLOODING

FIGURE 37

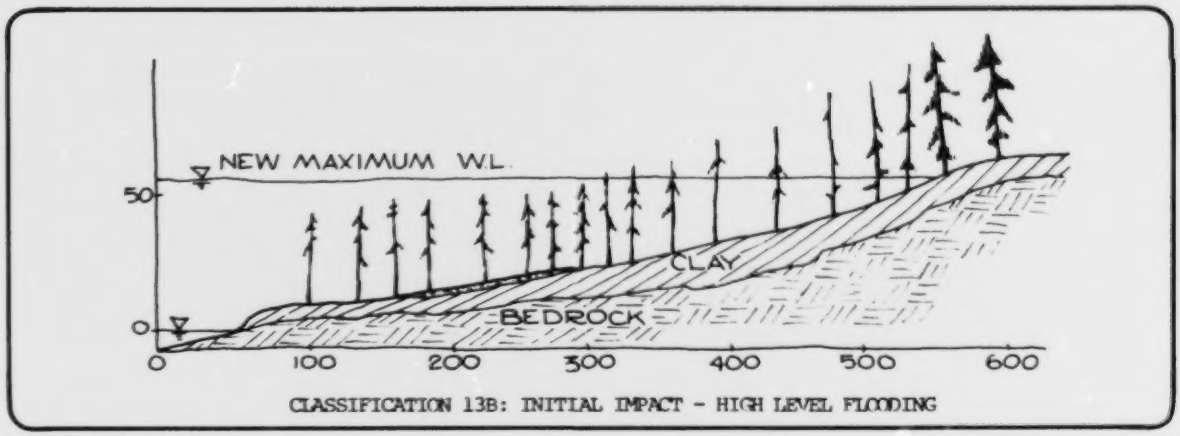
Low Level Flooding: In this situation, bank erosion may not commence immediately. The important variables are slope and exposure. Exposed shorelines with moderate banks may start eroding at once, while gently inclined banks may not be undercut to any great extent even on exposed sites (Figure 38). In this event, a narrow zone of timber will be inundated. The overburden will not be eroded away to bedrock within this period.



CLASSIFICATION 13B: INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 38

High-Level Flooding: In this situation a wide zone of forest will be inundated (Figure 39). Erosional processes at the new water line will be minimal due to the standing flooded trees. Impacted overburden shorelines, especially northern slopes, have a high potential of being permafrosted. In this case they would thaw immediately, creating unstable bank conditions.

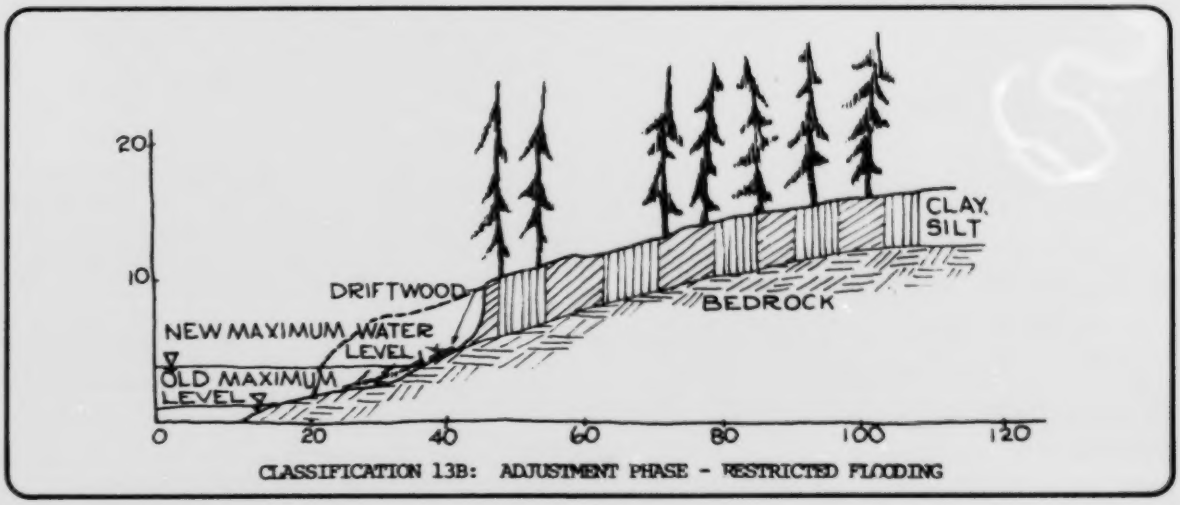


CLASSIFICATION 13B: INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 39

Adjustment Phase - In every flooding situation, the time required for the erosional processes to be completed is a function of exposure, mineral soil depth and composition, bedrock topography and width of inundated forest. Bank erosion will only cease when a bedrock control structure is reached. Until that time materials are constantly being eroded and undercut trees are accumulating. The concentration of fallen trees along a shoreline is a function of the shoreline exposure and configuration. Headlands can be expected to be partially cleared while less exposed sites remain congested. The driftwood build-up becomes crucial as it reduces the wave energy along the new water line. Consequently, erosion will stop, but a stable bank need not be achieved. Once the driftwood is removed erosional processes will continue until a sufficient amount of bedrock is exposed.

Restricted Flooding: During this phase, bank erosion will have been completed quickly once a wide rock beach is formed (Figure 40). The accumulation of driftwood would not be significant enough to slow the erosional rates down.



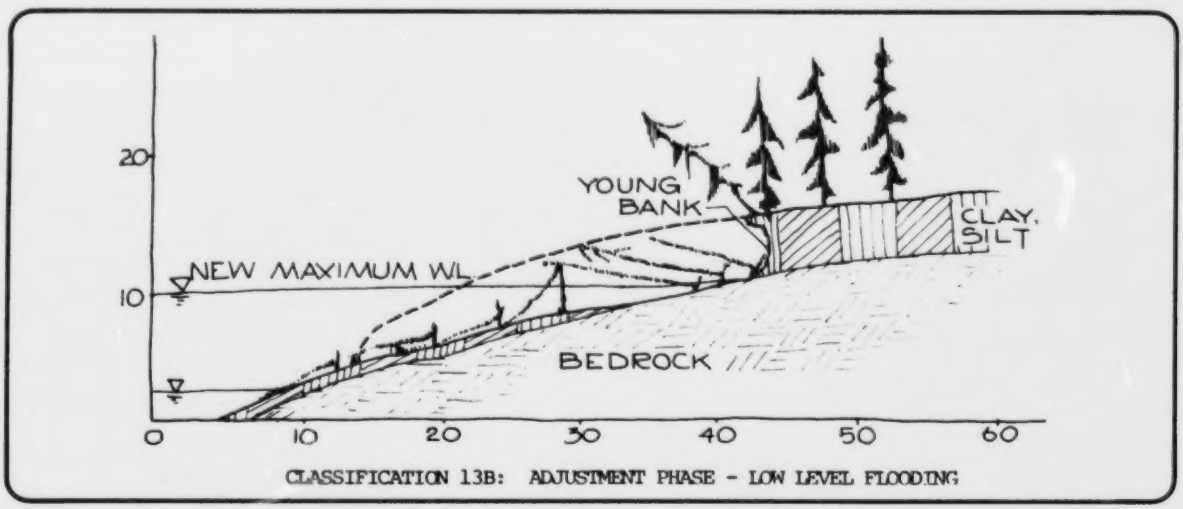
CLASSIFICATION 13B: ADJUSTMENT PHASE - RESTRICTED FLOODING

FIGURE 40

Low-Level Flooding: Once bank erosion starts, the bank will retreat until bedrock is reached. This distance is a function of the bedrock incline. The gentler the slope, the greater the shoreline recession. During this phase a bedrock shoreline would be achieved.

On exposed sites along Sipiwisk Lake, the clay bank had retreated two to four feet per year until a stable shoreline was achieved (Photograph 44). Erosional rates of less than one foot per year may occur on the less exposed sites.

With the shoreline recession a considerable amount of forest cover will be undercut (Figure 41). The root system and branches create enough drag to prevent the waves from removing the accumulation of trees. As a consequence, shoreline mobility and boat access is severely hampered. In most cases, few inundated trees will remain standing. Although the waves seldom hit the clay or silt bank above the exposed bedrock, the banks may not have achieved a natural state. "Lips" of vegetation will overhang the convex bank cluttering up the shoreline when they fall.



CLASSIFICATION 13B: ADJUSTMENT PHASE - LOW LEVEL FLOODING

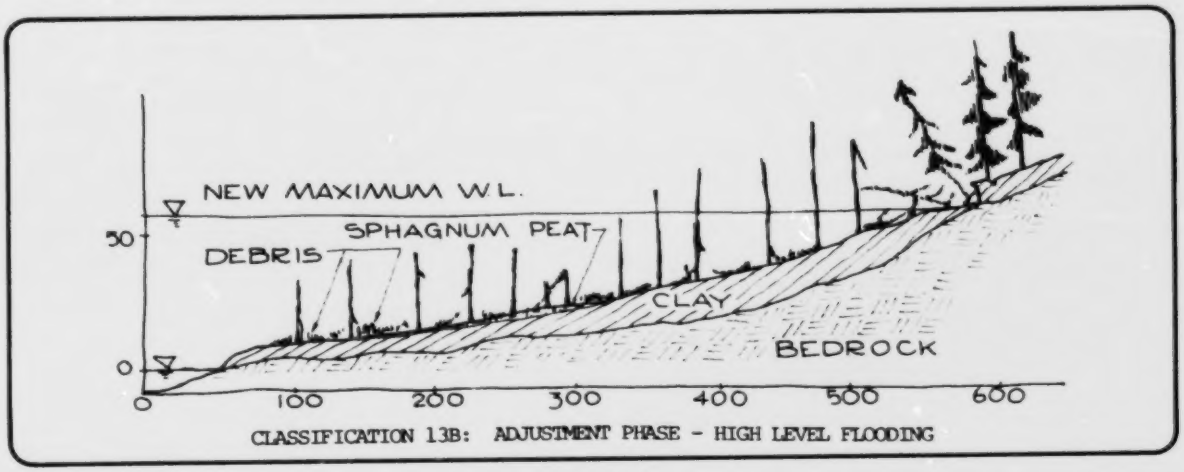
FIGURE 41

PHOTOGRAPH 44 - Sipiwisk Lake, flooded 1960. Water level rise - eight feet. Bank instability causes the trees to fall onto the shore. Note the few upright undercut trees on the bedrock.

High-Level Flooding: The offshore standing trees will affect the erosional rates to the extent that all processes will be inhibited for up to twenty years after flooding (Figure 42).

Ice movement may be an important agent helping to clear the offshore area of flooded standing trees. When the waves reach the overburden, erosional processes will be similar to the Low-Level Flooding situation. The offshore area can be expected to contain a substantial amount of detritus.

When the permafrosted overburden begins to thaw, the banks will remain unstable for some time. This will cause more trees to clutter the shoreline than would normally be expected.

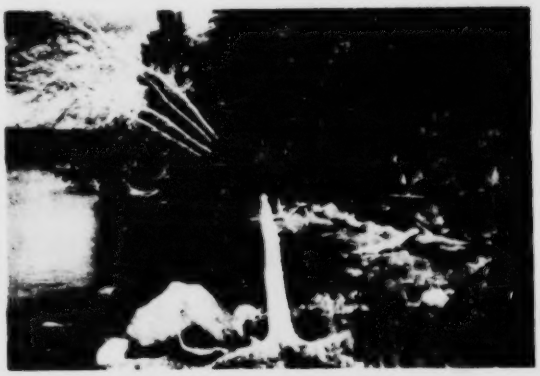


CLASSIFICATION 13B: ADJUSTMENT PHASE - HIGH LEVEL FLOODING

FIGURE 42

Fifty-Year Time Frame -
All Flooding Situations: The bare rock beach will be exposed to its highest water level in all flooding situations. In the majority of cases the banks will have achieved a stable state. All permafrosted sites should be melted out by this time, however, backshore slump cracks will create unstable conditions. This will increase the volume of material to be removed near the waterline (Photograph 45).

A significant amount of driftwood will be evident along protected shorelines and the stable banks will be colonized by shrubs and trees.



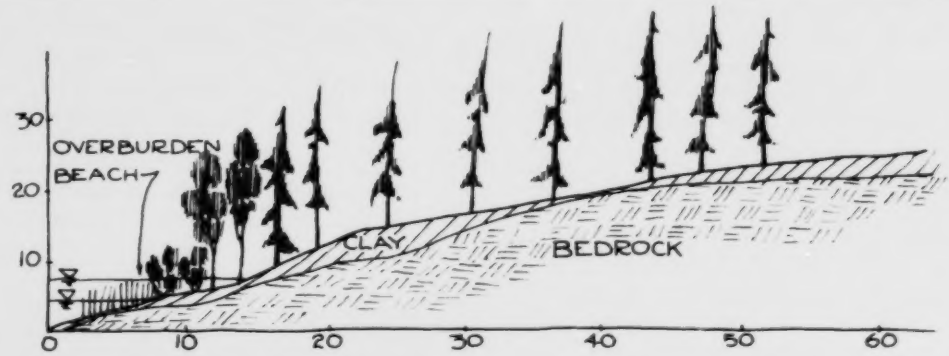
PHOTOGRAPH 45 - Lac Seul, flooded 1929, water level rise - ten feet. Although the shoreline is bedrock controlled, the bank materials are still eroding.

CLASSIFICATION 14 - BEDROCK CONTROLLED SHORELINE WITH OVERBURDEN BEACH:

Impact Sensitivity - After being impacted, these shorelines are very slow to recover because of the protective convave configuration. Wave action is the significant eroding influence.

Initial Impact -

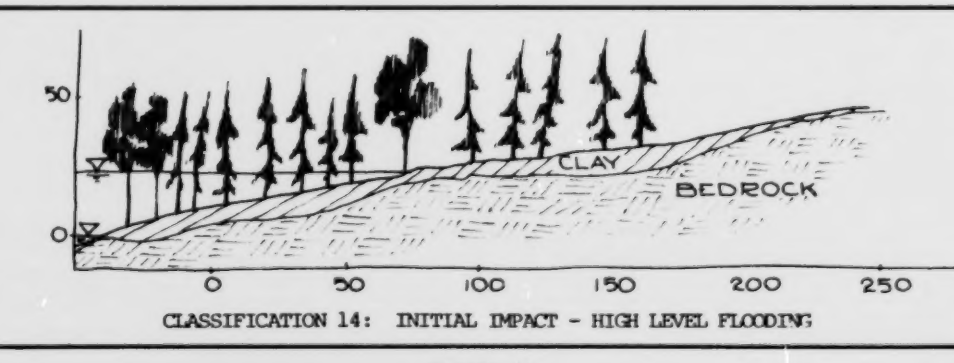
Restricted Flooding: The water level will remain within the upper limit of the overburden beach (Figure 43). A narrow zone of trees, often hardwoods, may be inundated. The marsh vegetation would not be totally eliminated.



CLASSIFICATION 14: INITIAL IMPACT - RESTRICTED FLOODING

FIGURE 43

Low-and High-Level Flooding: In these two situations a considerable amount of forest will be flooded (Figure 44). The swath of inundated trees will depend on the backshore slope and the level of flooding. The marsh vegetation would be eliminated due to the rise in water level.



CLASSIFICATION 14: INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 44

Adjustment Phase -

Restricted Flooding: Since these embayments are typically deposition sites, the beach would move back laterally. As new beach materials are built up they will be colonized by marsh vegetation typical of the former shoreline.

A shrub zone will be established in the upper limits of the water-washed zone. The majority of the inundated trees will remain standing for the larger part of this phase.

Low- and High-Level Flooding: In these situations recovery rates are slow. Erosion along the new water line will be negligible, consequently the majority of the inundated trees can be expected to remain standing for twenty to forty years (Photograph 46). The inundated, defoliated trees will allow the light to penetrate the ground cover resulting in the establishment of a narrow zone of grasses and shrubs along the shoreline. Few sites can be expected to be colonized by submerged and emergent vegetation due to the local environmental conditions. These conditions are caused by the decaying detritus, stagnant water, poor substrate and possible low nutrient supply.

PHOTOGRAPH 46 - Russell Lake, flooded 1952. Water level rise - ten feet. Extensive areas of dead standing trees are typical of flooded embayments in all reservoirs.

Fifty-Year Time Frame -
Restricted Flooding: Within fifty years these shorelines are expected to appear as they did before flooding. After the inundated trees fall, they will collect in the offshore area, but this will not be detrimental to any stabilization process.

Low and High-Level Flooding: Within fifty years a beach may have begun to form. Water-washed materials may be deposited in the bay. This is largely a function of wave action, and a source of erodible materials. Any buildup of materials is conducive to offshore colonization. The new shoreline will support new plant growth while aquatics will sparsely colonize the offshore bottom materials.

The beach and marsh will not develop to the extent it was before flooding.

CLASSIFICATION 15 - LOW BEDROCK CONTROLLED SHORELINE:

Impact Sensitivity - These shorelines will be effected in a manner similar to Type 13B shorelines. The erosive forces may be current or wave action, however, they will be reduced due to the protected nature of these shorelines. These linear shorelines will not stabilize at the same rate as headland shorelines (Photograph 47). A considerable amount of driftwood which will retard further erosional processes can be expected to occupy the shoreline. This is a function of the flooding level and the slope. The accumulating driftwood and detritus will also severely restrict movement along the shoreline and boat access.

There will be very little plant colonization occurring at the new water line within the Fifty-Year Time Frame, particularly under low and high-level flooding.

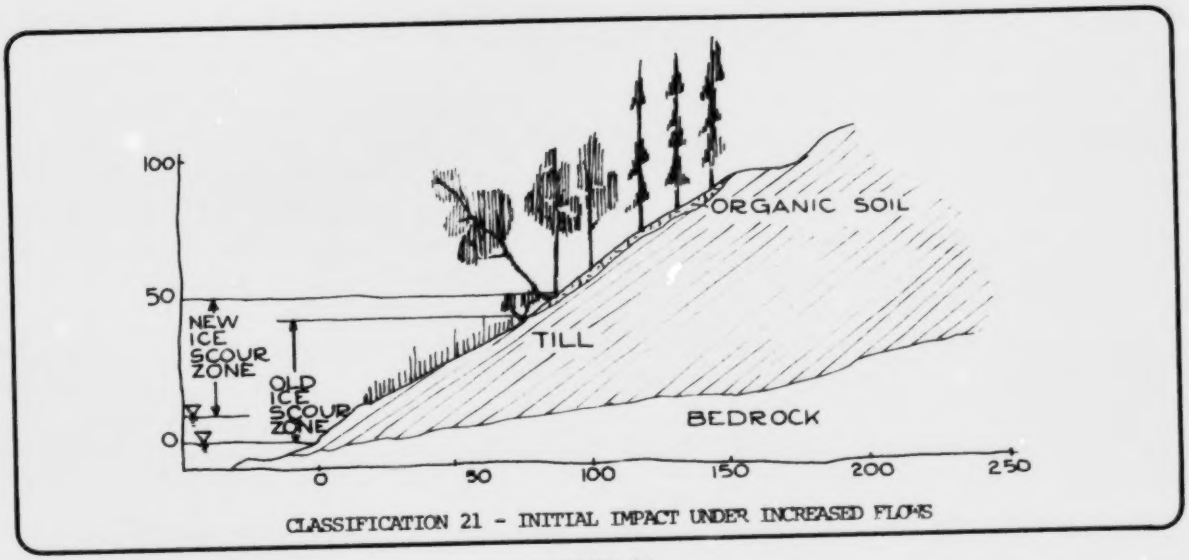
PHOTOGRAPH 47 - Low Bedrock Controlled Shoreline on Sipiwesk Lake, flooded in 1960. Water level rise - eight feet. The forest cover is still being undercut. The bank stabilization processes are slowed down by the driftwood barrier that is dissipating the wave action.

CLASSIFICATION 21 - ICE-SCOURED TILL BANK:

Impact Sensitivity - This shoreline will be subjected to increased water levels on the Lower Nelson River and decreased levels on the Lower Churchill River. The impact here will be one of an extension of the ice scoured bank up the slope along the Neslon and a substantial reduction of the ice scoured bank on the Churchill. The impacted channels will be dealt with separately.

Initial Impact Under Inreased Flows - An increase in discharge along the Lower Nelson River will result in approximately a two foot water level rise. The ice scoured zone will be extended up the bank by this amount (Figure 45). This is assuming that the ice conditions will remain the same under the increased discharges. The tremendous force of the ice is expected to begin removing trees from the overburden during this period. Initially, the shorelines may be cluttered with fallen trees but will be cleared after a few seasons of ice scouring. The swath of trees to be effected is a function of the actual water level rise, the ice condition and the slope.

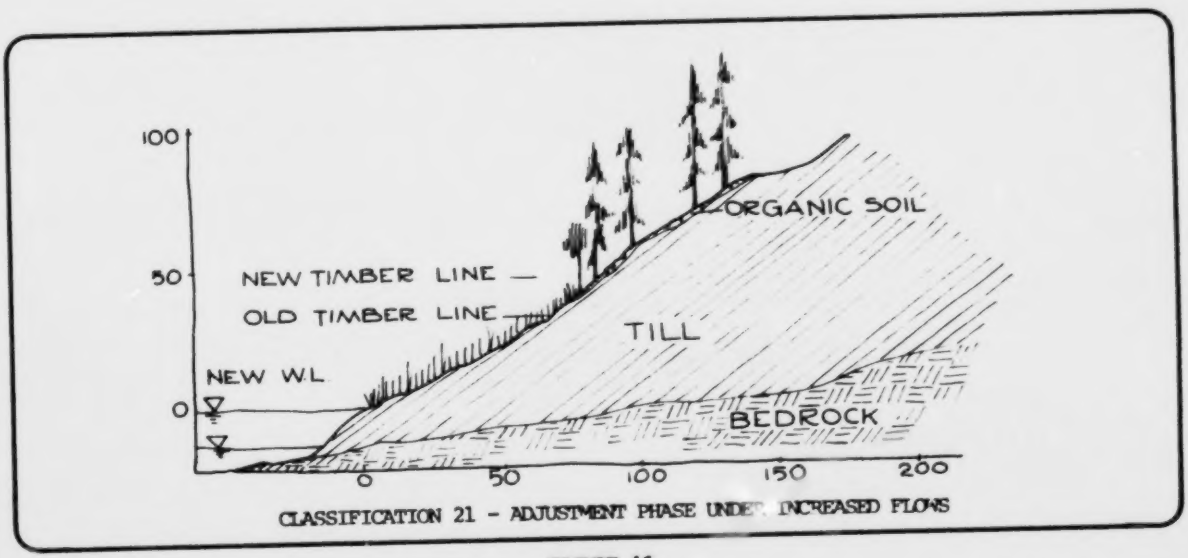
Due to the composition of the materials, the till is not expected to be substantially eroded. The organic layers will be removed until a more resistant substrate is reached.



CLASSIFICATION 21 - INITIAL IMPACT UNDER INCREASED FLOWS

FIGURE 45

Adjustment Phase Under Increased Flows - All organic soil and vegetation will be scraped off the till to the top of the new scour line (Figure 46). A colonizing zone of sedges and grasses will extend up to the new forest line. The felled trees will be removed from the site, collecting along the down stream shorelines. Many of these trees will reach Hudson Bay.



CLASSIFICATION 21 - ADJUSTMENT PHASE UNDER INCREASED FLOWS

FIGURE 46

Fifty-Year Time Frame Under Increased Flows - By the thirtieth year, the majority of the impacted shorelines will appear as they did in the pre-flooding state. A narrow zone of shrubs and trees will colonize the edge of the forest.

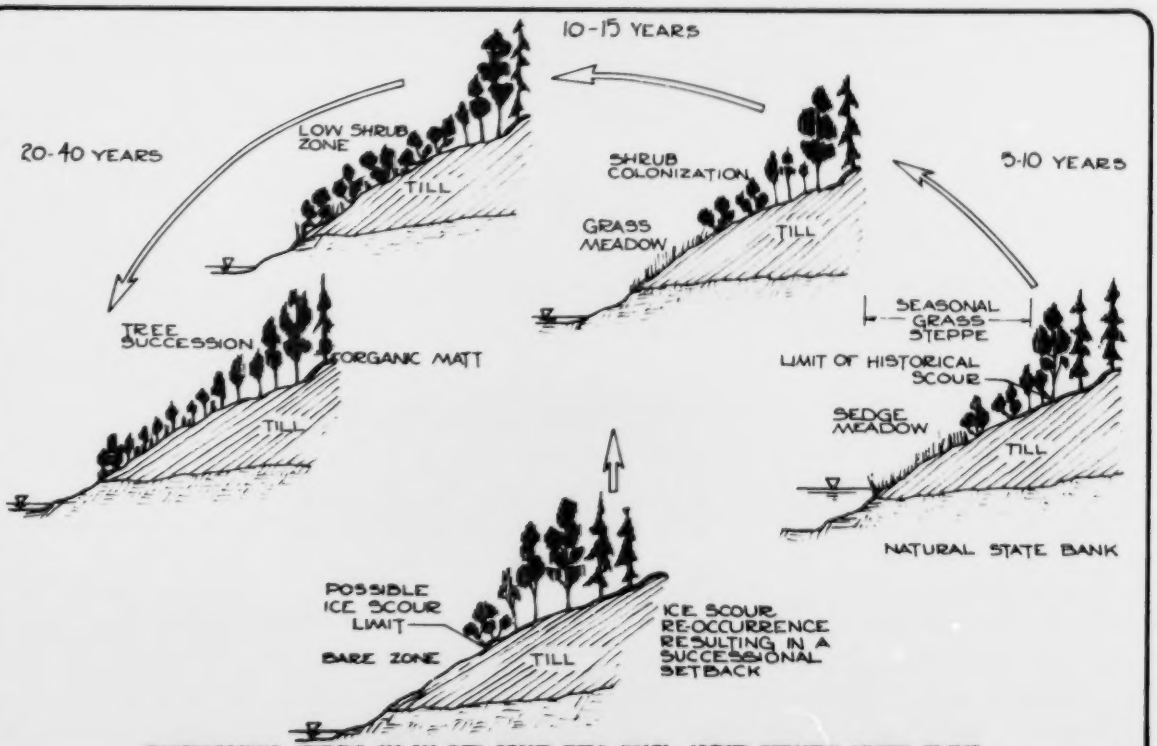
Impact Sensitivity Under Reduced Flows - The major change will be one of succession on the seasonal grass steppe. Banks heavily vegetated by sedge and grass under a natural state will be colonized by woody vegetation under water regulated conditions.

Initial Impact Under Reduced Flows - A reduction in the discharge along the Churchill River is expected to terminate the ice scouring action along the till bank. The type and rate of colonization to follow will be a function of the available materials. Exposed rock will remain barren while sites with mineral soil will be vegetated. The first noticeable change will be the replacing of sedge species by grass species.

Adjustment Phase Under Reduced Flows - On those portions of the banks no longer subject to flooding, the vegetation intolerant of the drier soil conditions will be phased out and replaced by species tolerant to the drier conditions. Early in this phase the sedges will be totally replaced by grasses and other herbaceous growth. Shrub and tree colonization processes will occur on the steppe where soil conditions are suitable. Within thirty years, shrubs will have colonized much of the bank area. Within this period, the hardwood trees such as balsam poplar will extend beyond the forest edge. The availability of hardwoods in the area before the reduction of the ice scouring will enhance the colonization processes (Figure 47).

The sedges and other moisture loving species will now be restricted to a lower and a narrower water flushed zone. The width of newly exposed bank will depend upon the particular channel profile. Exposed alluvial materials will be colonized by water loving plants while exposed rock surfaces will support no new plant life (Photographs 48 & 49).

Should there be a reoccurrence of the ice scour phenomenon during years of high water flow, the woody vegetation within the scour zone will be removed. This

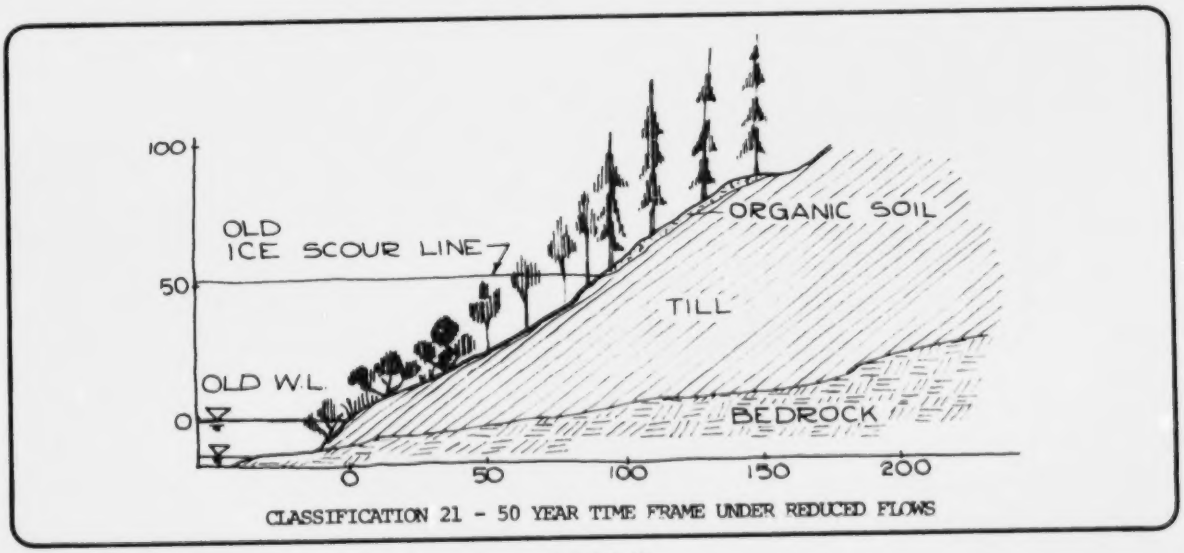


SUCCESSIONAL TRENDS ON AN ICE SCOUR TILL BANK, UNDER REDUCED WATER FLOWS

FIGURE 47

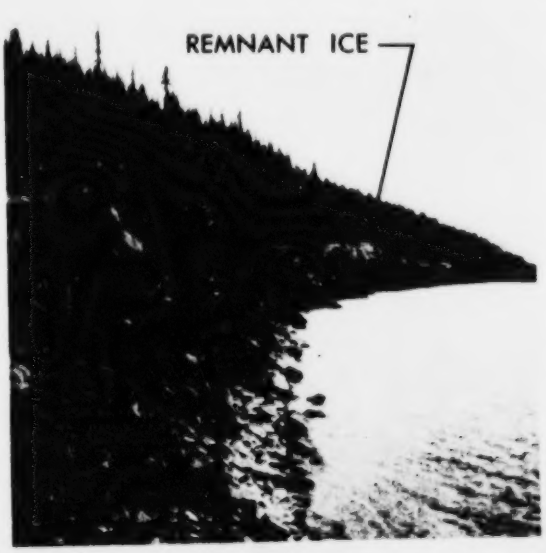
will set all colonization process back to what they were under a natural regime. As a consequence, a substantial amount of plant debris would be added to the water system.

Fifty-Year Time Frame Under Reduced Flow (Figure 48) - Under ideal conditions, the upper portions of the grass steppe banks will be covered with hardwood tree growth. Once established, poplars will quickly colonize an area. A wide shrub zone will exist in the upper limits of the water washed zone. Boulder and rock surfaces will show little sign of colonization within this time frame.



CLASSIFICATION 21 - 50 YEAR TIME FRAME UNDER REDUCED FLOWS

FIGURE 48



PHOTOGRAPH 48 - Ice scoured till bank on the Lower Churchill River. The rock rubble is not colonized under natural conditions and will likely remain barren when the Churchill flows are reduced.

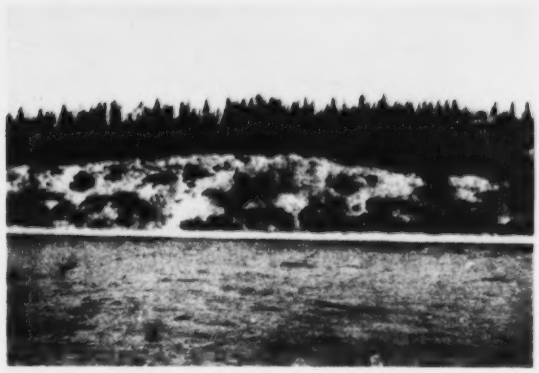
PHOTOGRAPH 49 - Abandoned channel of the Ogoki River, 1941 Diversion. The colonization process among the rocks has been negligible within 24 years after the discharges were reduced. Even around the forest edge, shrub colonization is poor due to the lack of soil.

CLASSIFICATION 22 - SHORELINE IN COARSE SEDIMENTS:

Impact Sensitivity - Under natural conditions, Type 22 shorelines are not entirely stable as the banks continuously erode. Natural weathering and wave erosional process keep these shorelines in a quasi-equilibrium state. Although they are very susceptible to accelerated erosional forces they attain a natural state of erosion rate within a short period.

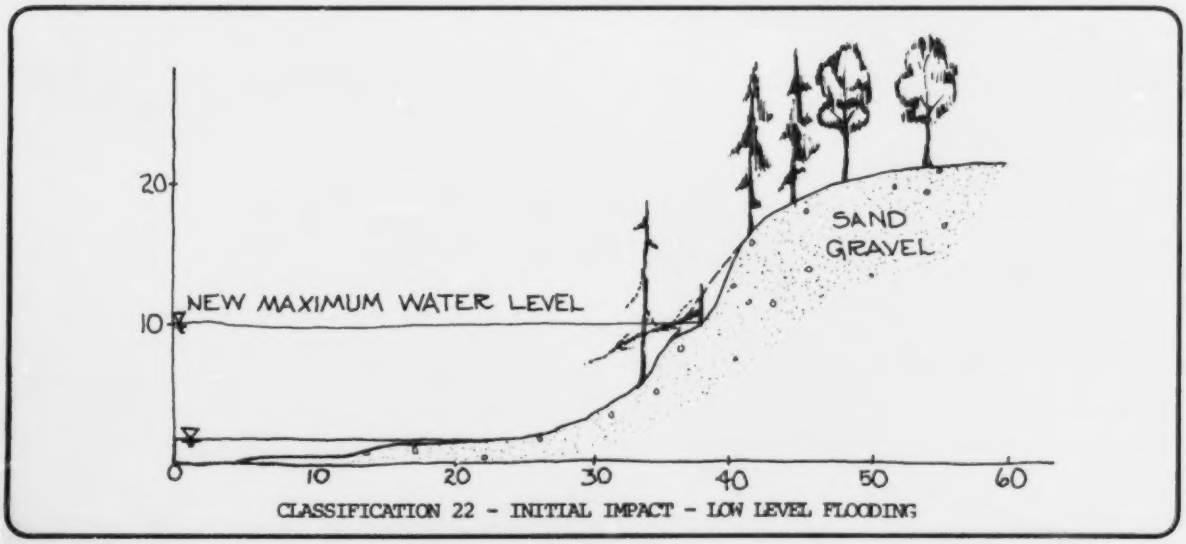
Once impacted, the reworking of eroding materials into a beach and offshore bench is instrumental in dissipating wave energy. Wave energy is not the only erosive force. The effect of alongshore currents on the shoreline is one of material removal and relocation (Photograph 50), which in itself may cause unstable conditions. Materials removed from the base of the bank are replaced by the surface ravelling of bank materials.

The ultimate shoreline shape is a function of the water level increment, exposure to wave and current energy, height of bank and type of bank materials.



PHOTOGRAPH 50 - A natural state, Type 22 shoreline. These granular slopes are naturally unstable. The surface ravelling is moving living matts of undercut vegetation slowly down the slope surface.

Initial Impact -
Restricted, Low and High-Level Flooding: All three flooding situations will be dealt with at once as the processes will be similar. Stabilization processes will take longer and a greater volume of materials will be eroded under Low and High-Level Flooding conditions (Figure 49).



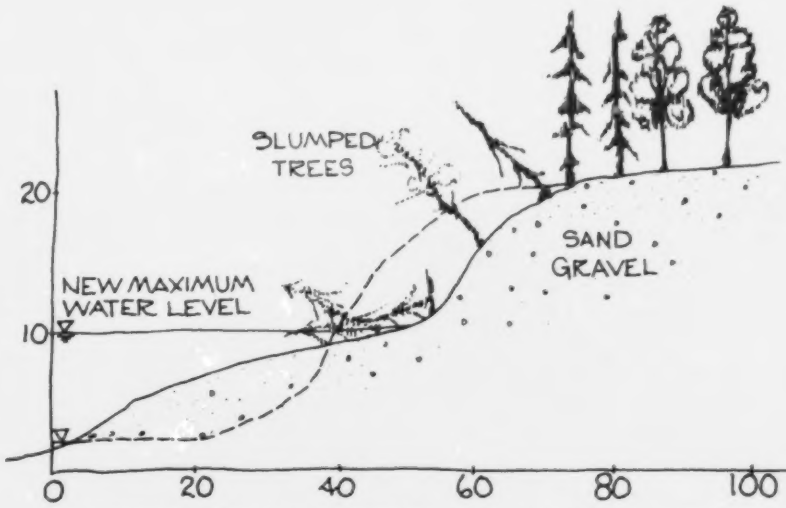
CLASSIFICATION 22 - INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 49

Initially the materials will be eroded by wave action and slope ravelling will occur. This will be quite dramatic on exposed sites. Undercut, overlying vegetation will slide down the slopes, accumulating at the water's edge. The accellerated erosion will continue until a sufficient amount of material has accumulated in the offshore area.

Adjustment Phase -
Restricted, Low and High-Level Flooding: The recession of Type 22 shoreline will depend on the water level increment and the height of the bank. The higher banks will receed the least under all flooding conditions as the higher the bank, the greater the volume of material removed per unit of horizontal retreat. In all three flooding situations the eroded materials will accumulate in the offshore area resulting in the formation of a beach of an offshore bench. The beach and bench are instrumental in stablizing the shoreline by dissipating the wave energy and preventing it from eroding the base of the bank. The bank will achieve a natural state when a shore profile similar to the former natural profile has been established at a higher elevation. The newly created beach will be formed to the highest water level. The water sorting action will result in the coarse materials (pebbles) overlying the beach while the light size materials (fine sands) will be carried offshore by wave action to form the beach.

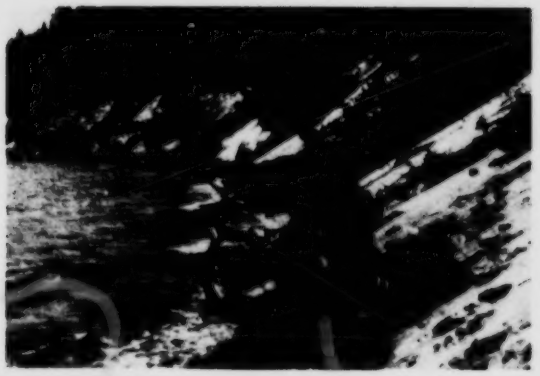
Under Restricted and Low-Level Flooding conditions, the accelerated erosional processes will have ceased within a ten year period (Figure 50). The stabilization processes are expected to last longer under High-Level Flooding conditions. The amount of undercut vegetation is a function of the horizontal retreat. In the majority of cases, little driftwood and detritus will be evident along the new shoreline (Photograph 51).



CLASSIFICATION 22: ADJUSTMENT PHASE - LOW LEVEL FLOODING

FIGURE 50

PHOTOGRAPH 51 - Esker on the shoreline of Russell Lake, flooded 1952. Water level rise ten feet. This impacted esker has developed a beach and offshore bench. Note the gradation of the materials along the beach.



PHOTOGRAPH 52 - Lac Seul, flooded 1929. Water level rise was ten feet. Materials at the base of the bank are still eroding causing surface ravelling. Note the banks are only sparcely colonized by annual plants and some grasses.

Fifty-Year Time Frame -
Restricted, Low and High-Level Flooding:
By this time, the majority of the beaches and benches will be well developed resulting in a natural state shoreline. A few exposed banks may still be unstable, consequently surface ravelling is greater than normal causing large chunks of vegetation to be undercut (Photograph 52). The matts will slide down the slope and break up at the base of the bank. A Type 22 shoreline observed at Lac Seul was still actively eroding 44 years after flooding.

In most situations there will be little driftwood along the shoreline. All banks will be sparcely colonized due to ravelling of surface materials.

CLASSIFICATION 23 - CLAY SHORELINE OF MODERATE HEIGHT AND MILD SLOPE:

Impact Sensitivity - This river type shoreline is in a dynamic state; materials are constantly being eroded and deposited along the channel. The size of the channel is in a state of equilibrium with the volume of flow. An increase in the volume of flow will cause an increase in the size of the channel by deepening and widening, as well as by increasing the elevation of the water surface. The progressive widening of the channel over a period of time will steepen the banks and cause bank slumping and removal of trees. The extent of channel widening and deepening are considered in site-specific statements. The deepening is likely to be completed first followed by the completion of the widening within 10 to 20 years.

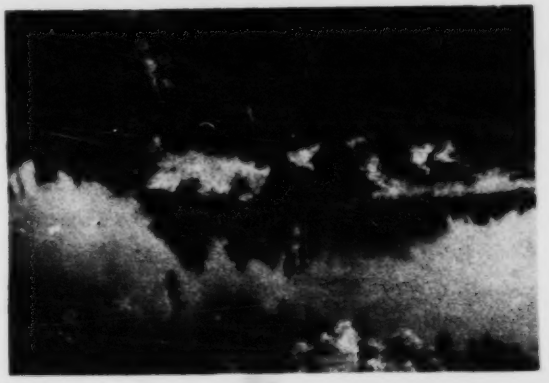
Initial Impact -

All Levels of Flooding: Inundated vegetation will be killed. Trees near the former waters edge will be undermined by erosion or felled by ice action.

Adjustment Phase -

All Levels of Flooding: The undermining of trees and destruction of trees by ice action will proceed laterally to the new waters edge. In many cases the destruction of vegetation will be accelerated by slumping of the oversteepened bank, accentuated in some cases by the melting of permafrost. Where the channel enlargement is not sufficient to undermine trees by erosion, the trees will likely be destroyed and removed by ice and current action. As the new equilibrium position is approached the rate of erosion will decrease.

An impacted Type 23 shoreline was observed on the Root River in north-western Ontario. In 1957, Ontario diverted some of the waters of Lake St. Joseph through the Root River into Lac Seul, increasing the flow in the River from a low value up to a maximum of about 6,000 cfs. In this case of Restricted Flooding, the increased velocities undercut the silty overburden in narrow sections of the river creating an unstable bank as shown in Photograph 53. The soil eroded from such narrow sections was deposited in wider downstream sections to form Type 24 and 28 shorelines as discussed in the following pages and shown in Photograph 54.



PHOTOGRAPH 53 - Root River velocities were increased in 1957. Emergent vegetation is slowly building up on the alluvial beach.

Fifty-Year Time Frame -

All Flooding Situations: Stability will be achieved on most sites. Banks may remain slumping even though shoreline erosion has halted. Localized areas, primarily river bends, may still be eroding and stretches of channel will be accumulating alluvial materials. These deposits are conducive to the colonization of grasses, sedges and shrubs.

It should be noted that water levels in the Rat-Burntwood Rivers below Notigi after diversion will typically be higher in winter than in summer. Winter ice surcharge will have a destructive effect on vegetation above the summer water level. It is discussed further in Sections 5.4.4 and 6.3.3.

CLASSIFICATION 24 - ALLUVIAL SHORELINE AND CLASSIFICATION 28 - LOW WILLOW SHORELINE:

Impact Sensitivity - The flooding impact on Type 24 and Type 28 shorelines will be discussed together as both shorelines will be affected in a similar manner due to their low relief. The genesis of both shorelines, which normally takes decades, are due to allogenic successional processes. Therefore, it is unlikely that the depositional land forms (especially Type 24) will be recreated at a higher level within a fifty year period.

In the case of restricted flooding the effect is simply to shift the zones of typical vegetation upward and landward, a process which may be substantially completed in a period of ten years. This process will apply to both impacted Type 24 and 28 shorelines. In the case of low or high level flooding the low backshore of these shorelines will be inundated and the new shoreline may form opposite a terrain differing from that at the existing shoreline. In this case the existing shoreline is not a useful indicator of the type of new shoreline to be anticipated. Under these conditions a Type 28 shoreline could be expected to evolve over an extended period of time. In most cases, it is unlikely that a Type 24 shoreline will develop.

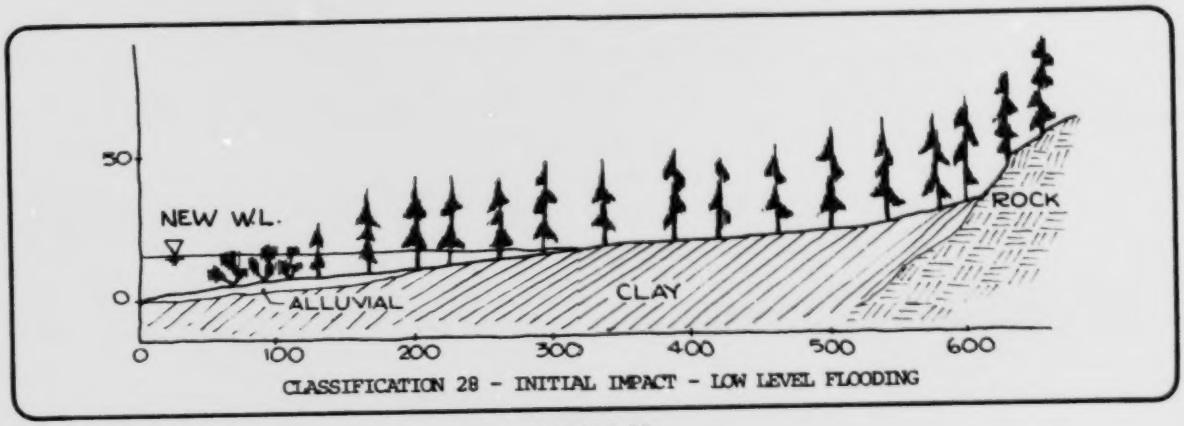
Initial Impact -

Restricted Flooding: In Types 24 and 28 shorelines the new water level will remain within the shrub zone (Figure 51). Along the river channels, currents will be the main erosive force while on lake shores wave action has greater impact. As both these shorelines already exist along sheltered stretches it is doubtful that the accelerated erosional process will be significant. The immediate effect will probably be shrub mortality. Shrubs may not die back until the 4th year of flooding as the critical factor causing shrub mortality is the lack of oxygen in the soil. The actual depth of water is not critical after the roots are flooded. This root suffocation is also the cause of tree mortality, although mortality occurs sooner. The raised water table may kill a few trees in the backshore area. Most of the marsh vegetation will adjust to the new level.

CLASSIFICATION 28 - INITIAL IMPACT RESTRICTED FLOODING

FIGURE 51

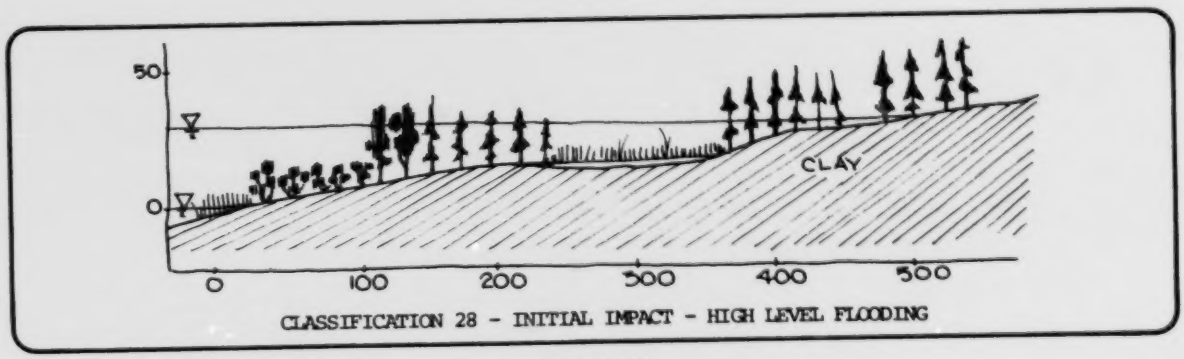
Low Level Flooding: The water level will rise above the shrub zone but is assumed to remain within the typical shoreline backshore area (Figure 52). In this case the water level rise is sufficient to eliminate the offshore and shoreline vegetation and flood a swath of forest. Erosion will be minimal at the new water line due to the standing dead trees in the offshore area.



CLASSIFICATION 28 - INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 52

High Level Flooding: Under these conditions the majority of Type 24 and 28 shorelines will not become re-established. Type 28 shorelines were observed to be developing on the Kettle Reservoir in mild sloping embayments. The determining factors here seem to be the slope at the new water line, the materials and the removal of inundated trees (Figure 53).



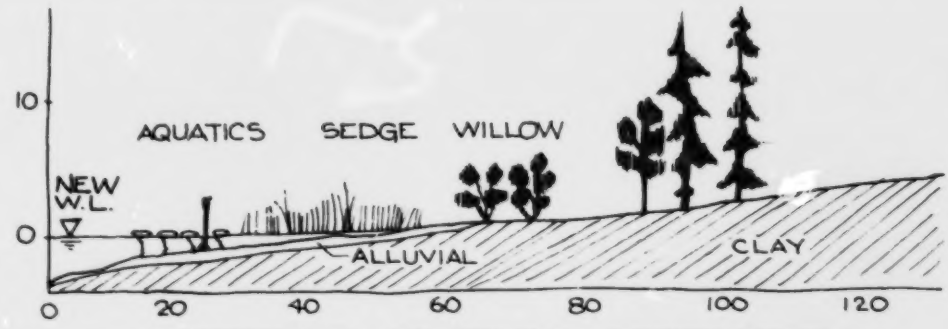
CLASSIFICATION 28 - INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 53

Adjustment Phase -
Restricted Flooding: Throughout the system the availability of material for deposition is expected to be greater during the adjustment phase when the majority of overburden is eroded in other areas. It may therefore be assumed that the alluvial deposition processes will create suitable substrate for autogenic successional processes during this phase. This is largely a function of river velocities, energy and the type of eroded materials. Generally eroded silts will be reworked to form

bars and levees long before eroded clays. The clays tend to go into suspension moving further down stream where they will settle after the water velocities decrease (Figure 54).

The inundated shrubs will decay and likely be removed while the inundated trees will remain standing. Shrub colonization will probably be well underway within 20 years after flooding while species of grass and sedge may become established in the dead shrub and tree zone within 5 years.

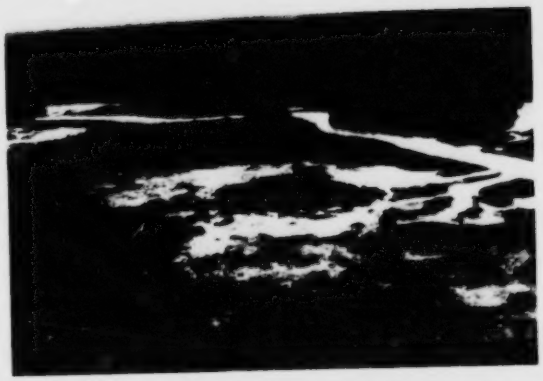


CLASSIFICATION 28 - ADJUSTMENT PHASE - RESTRICTED FLOODING

FIGURE 54

An example of an impacted Type 24 shoreline was noted along the Root River of north western Ontario. As a result of diverting water from Lake St. Joseph into the Root River, the increased velocities caused minor channel widening in overburden materials that were predominently silts (Photograph 54). As a consequence, the down stream alluvial type shorelines were built up and silt bars were formed where the channel passed through shallow lakes. Backshore flooding was extensive along low shorelines but the area is recolonizing with sedges and shrubs, 17 years after flooding (Photograph 55).

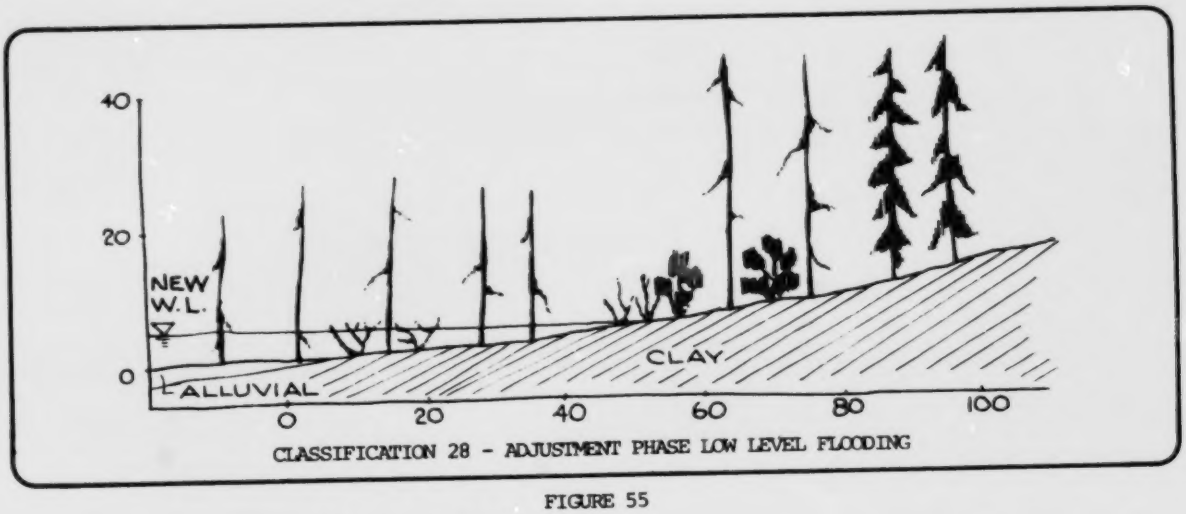
PHOTOGRAPH 54 - Root River velocities were increased in 1957. Alluvial materials have been added to the old shoreline in wider areas of the river. Present vegetation has helped to increase the depositional processes.



PHOTOGRAPH 55 - Root River velocities were increased in 1957. Flooding extended into the backshore killing the trees. The area is slowly being colonized by sedges, grasses and shrubs.

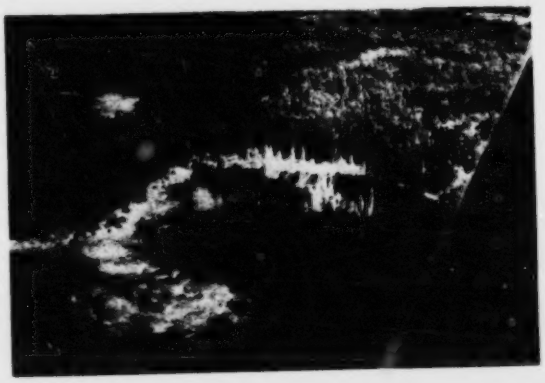
Low Level Flooding: In this case a substantial amount of standing dead trees will be present along the new water line. The majority of the trees will not likely be removed but decay in situ. These sites can be expected to contain a substantial amount of driftwood and detritus. The deposition of materials will be minimal along most shorelines.

The rate of shrub colonization within the water washed zone is largely dependent on shrubs already present in the backshore area. The shrubs present may not be able to tolerate the new moisture region along the shoreline (Figure 55). In this case the colonization processes will take longer. They may begin after the inundated trees are defoliated allowing light to penetrate the forest floor (Photograph 56). Grasses and sedges will likely be the first growth on the new shoreline.



CLASSIFICATION 28 - ADJUSTMENT PHASE LOW LEVEL FLOODING

FIGURE 55



PHOTOGRAPH 56 - Russell Lake, flooded 1952. Water level rise - ten feet. A shrub zone is establishing along this sheltered shoreline.

High Level Flooding: Within 4 years of flooding at the Kettle Reservoir a swath of willows ten feet wide was observed growing along a mildly sloped clay shoreline. Rushes and cattails occupied a twenty-foot wide zone in the offshore area. The site was devoid of dead standing trees but contained offshore detritus (Photograph 57). It would seem as if the absence of trees or clearing of trees shortly after flooding allowed for the colonization of these species. Other sites in the reservoir that seemed identical to this one, except for the inundated trees, were not colonized by willows or sedges.

PHOTOGRAPH 57 - Kettle Reservoir, flooded 1970. Water level rise less than 98 feet.

This embayment is quickly being colonized by shrub and marsh plants. This is the site of an old burn. Jack pine in the backshore is a good indicator of burned over terrain. The sparseness of trees along the new waterline is likely one of the reasons for the rapid colonization of the water tolerant species.

50 Year Time Frame -
All Flooding Situations: Evidence of depositional processes can be expected to be evident along restricted and possibly low level flooded shorelines. Generally there will be more dead trees along lake shores than river channels. Inundated trees should not be detrimental to colonization processes, which should now be well advanced. The extent of the marsh and shrub vegetation will depend upon the width of the water washed zone which is a function of the slope and water level fluctuation. Generally, the gentler the slope and the greater the fluctuation, the wider the marsh and shrub zone. In most reservoir situations the water washed zone will be narrow due to the reduced water level fluctuations (Photograph 58).

PHOTOGRAPH 58 - Lac Seul, flooded 1929. Water level rise ten feet. Along this embayment sedge and willow colonization processes are still occuring in a narrow zone. Note the offshore dead broken off trees.

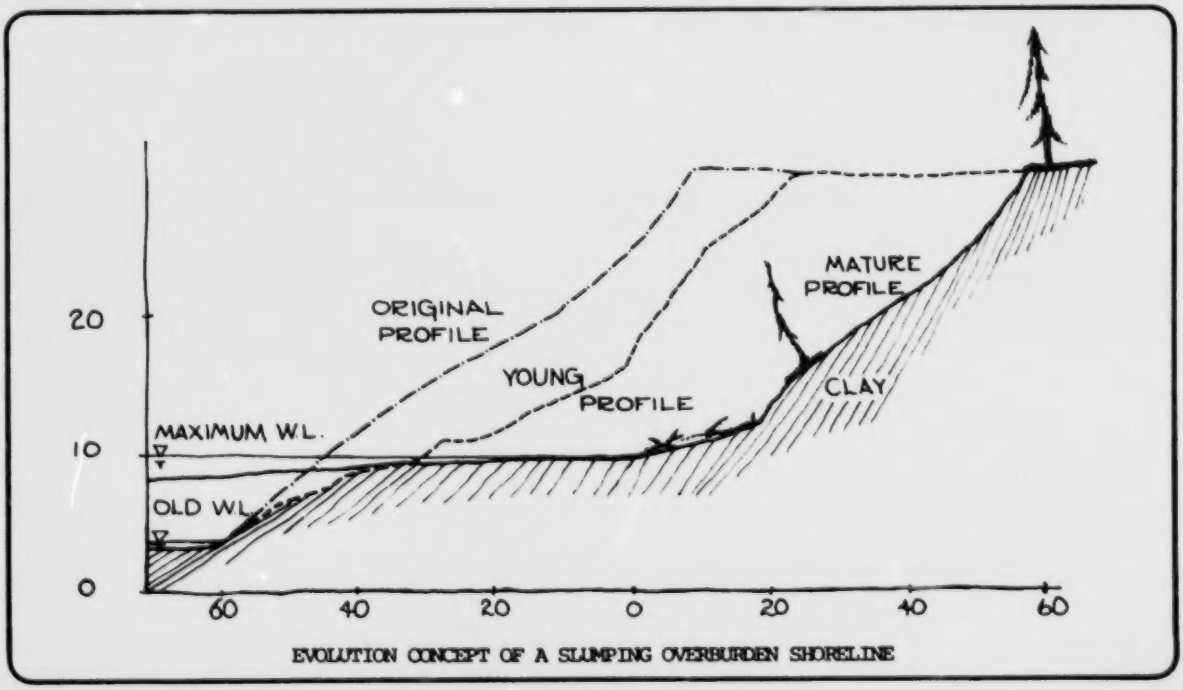
CLASSIFICATION 25 - SLUMPING OVERBURDEN SHORELINE (Figure 56):

Impact Sensitivity - The height and materials of the overburden bank make this shoreline very vulnerable to all water level increments (Photograph 59). Even under natural conditions these shorelines are highly unstable. Overburden materials are continuously slumping due to erosion at the base of the bank or melting out of permafrosted materials. Due to this bank activity, the slopes are seldom colonized. All vegetation present is derived from the undercut forest. The gradual movement of the matts down the slope allows the undercut trees to adjust to their new incline (Photograph 60).

Although these impacted shorelines will not stabilize their profile will change as they reach a natural state. On most lake situations the young bank slopes will level out to form a mature profile after an offshore bench has formed. This bench is instrumental in dissipating wave energy, thereby allowing for the development of a mature profile. Shorelines exposed to severe wave action or current conditions not conducive to producing a bench, may always possess a young profile. This is also a natural condition.

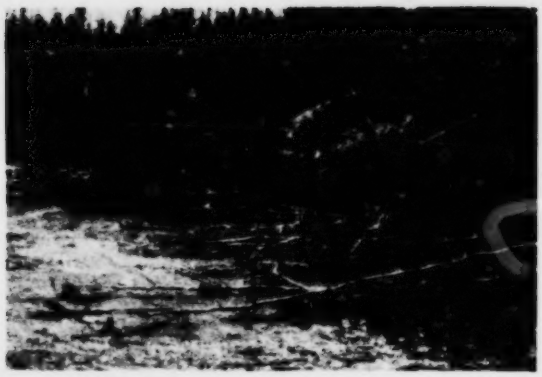
Sites that contain permafrosted overburden will likely erode faster, reaching a mature profile in a shorter period than non permafrosted sites. Initially the eroded overburden will increase water turbidity. Water clarity will improve once the accelerated erosion has ceased.

Along these shorelines the ultimate shape is a function of the water level increment, exposure to wave and current energy, height of bank and type of bank materials.



EVOLUTION CONCEPT OF A SLUMPING OVERBURDEN SHORELINE

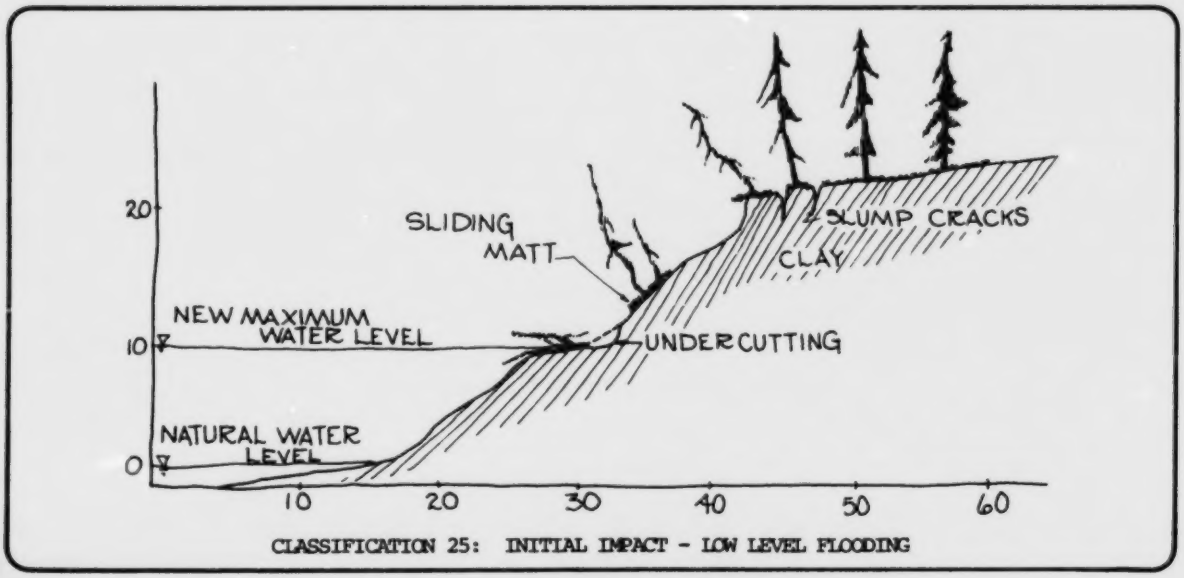
FIGURE 56



PHOTOGRAPH 59 - Three Point Lake, a natural state Type 25 Shoreline. Although the eroded materials have formed a wide offshore mud flat, the slope is still actively eroding. This site was not permafrosted.

PHOTOGRAPH 60 - Bank movement on a Type 25 slope is a gradual process as indicated by the angle of tree growth. Tree leaders have adjusted to their new incline as the matt slowly moved down the slope. Most matts sliding on these banks support living flora.

Initial Impact -
Restricted, Low and High Level Flooding: All 3 flooding cases will be dealt with together as the impacts are similar. Essentially the slope will be eroded until a sufficient amount of overburden has accumulated in the offshore area, thereby dissipating wave energy. Initially the accellerated wave or current action will erode the bank at the new water level. This erosion will cause larger than normal amounts of vegetation to be undercut and likely slide down the slope (Figure 57).



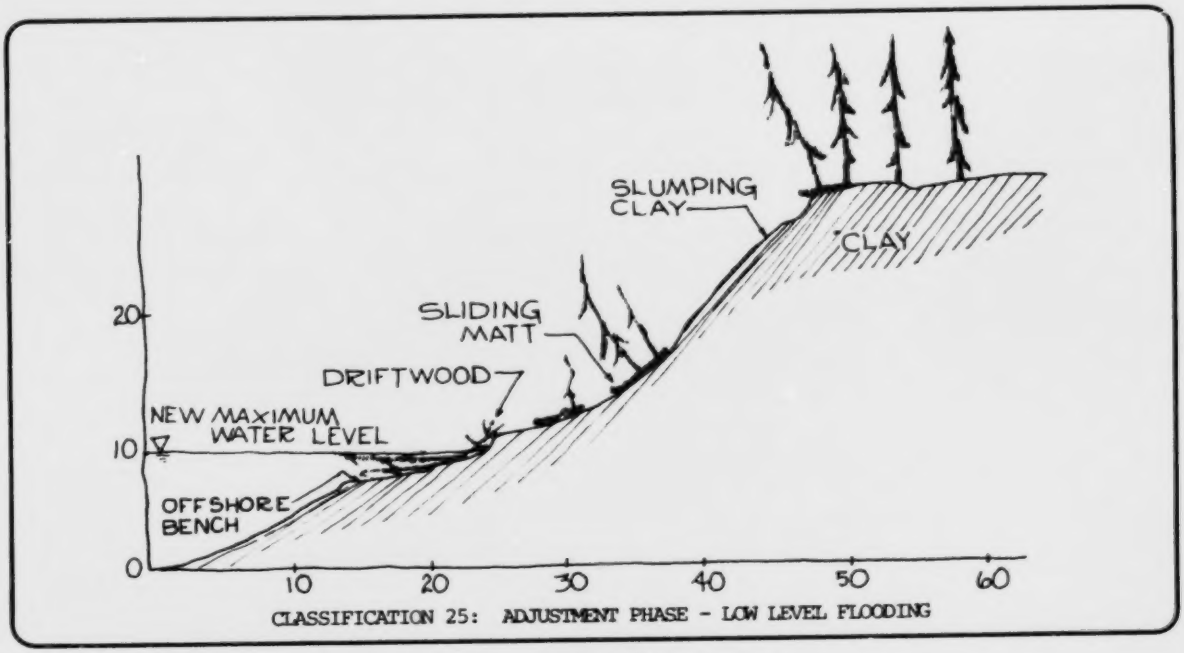
CLASSIFICATION 25: INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 57

Adjustment Phase -

Restricted, Low and High Level Flooding: The water level increment, the exposure and the overburden type will determine the time required for the shoreline to achieve a natural state (Figure 58). The higher banks will receed the least as the higher the bank, the greater the displaced volume of material per unit of horizontal retreat. A large number of matts will continue to slide down the slope until the accellerated erosional processes have ceased. The matts will tend to clutter the shoreline of lakes but will be removed along river channels. In lake situations the accumulating trees may prevent wave action from undercutting the shore and retard the evolutionary process (Photograph 61).

Restricted Flooding cases will likely adjust to the new water level increments early in the adjustment phase. Low Level Flooded sites will likely adjust over a longer period while High Level Flooded sites may take still longer.

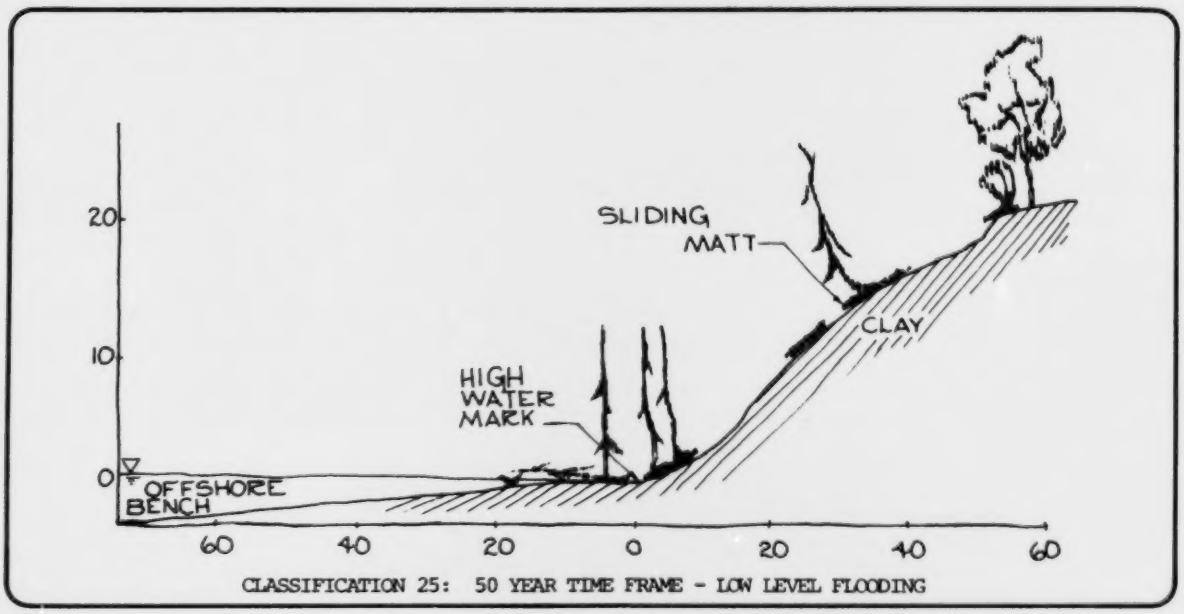


CLASSIFICATION 25: ADJUSTMENT PHASE - LOW LEVEL FLOODING

FIGURE 58

PHOTOGRAPH 61 - Sipiwesk Lake, Type 25 Shoreline, flooded 1960. Water level rise - eight feet. The accumulated undercut trees are instrumental in dissipating the eroding wave action. As a consequence, a natural state shoreline has not yet been achieved.

Fifty-Year Time Frame -
Restricted, Low and High-Level Flooding: Most exposed shorelines will have achieved a natural profile within fifty years (Figure 59). Bank erosion may not be complete on shorelines that have accumulated a substantial amount of debris. This will likely occur on low banks under low and high level flooding conditions. Erosion process will commence once the driftwood barrier breaks down and allows the wave action to erode the overburden slope.



CLASSIFICATION 25: 50 YEAR TIME FRAME - LOW LEVEL FLOODING

FIGURE 59

CLASSIFICATION 26 - TREED MUSKEG SHORELINE:

Impact Sensitivity - Treed muskeg shorelines are one of the most severely affected. The low nature of the terrain, the volume of inundated timber, the occurrence of permafrost, backshore water logging and possible muskeg floatation all contribute to the severity of impact along these shorelines.

Under natural conditions these shorelines are not stable. Along certain shorelines the wave action may be continuously undercutting the peat materials causing the over-lying vegetation to slump into the water (Photograph 62). Under these conditions any water level increment will accelerate the erosional processes at the new water line.

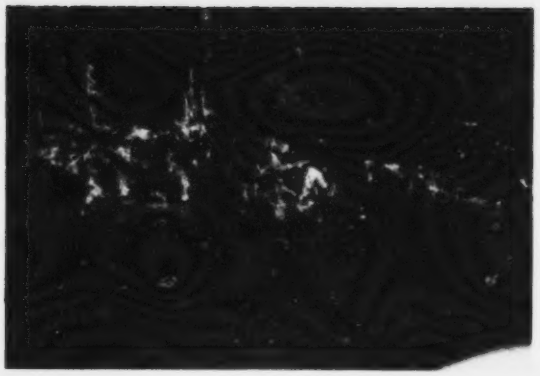
Due to the low relief of these shoreline, waterlogging is crucial under most flooding situations. When the water levels rise, the peat substrate becomes saturated suffocating the plant roots. A swath of dead standing timber can be expected to extend into the backshore area beyond the open water.

Where permafrost is present, the erosional process can be expected to accelerate under flooding conditions. Once the thermal equilibrium is upset large scale collapsing of peat and/or mineral soil will occur along the shoreline and backshore area. The severity will depend upon the amount of frozen substrate, the slope and the materials present.

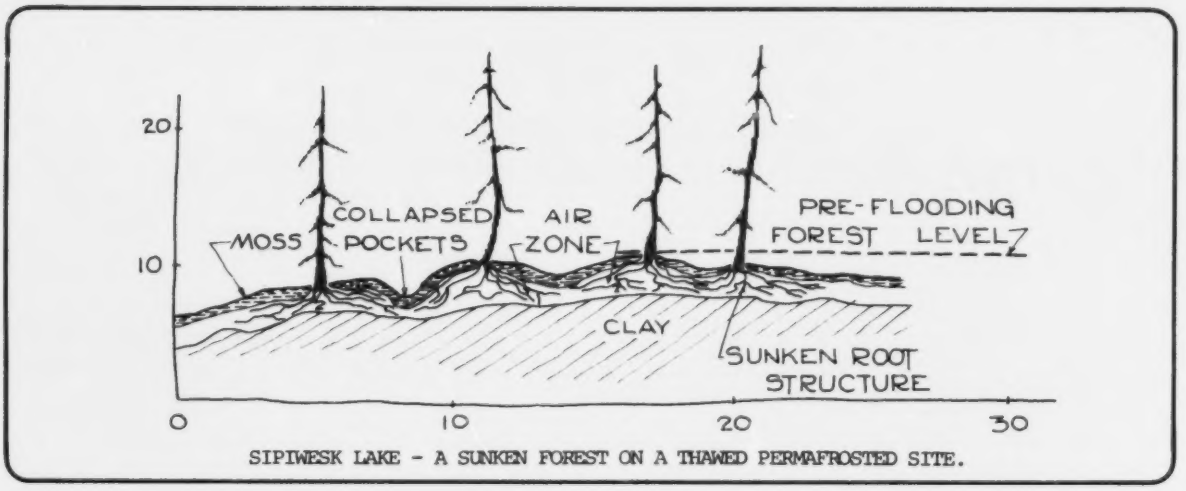
Where the slope is gentle the peat overburden shallow, surficial depressions may be formed in the backshore area as the permafrosted peat and/or mineral soil thaws. Such a case was observed on Sipiwesk Lake. This was characterized by dead standing trees and sunken pockets on the forest floor (Figure 60). Evidently the lowering of the mineral soil left the forest root system dry. This air pocket zone created by the removal of the ice zone resulted in root desication. Water logging did not seem to be the cause of species destruction. The ground flora consisted of liverworts, Sphagnum and feather moss, (Photograph 63).

This thawing out of permafrost can be very crucial with regards to site stability. Craters four feet deep were observed on cleared permafrost muskeg in the kettle reservoir.

The occurrence of floating treed muskeg is one of the more interesting and poorly understood flooding phenomenon. Large, mobile, moderately treed islands were observed in Kettle and Kelsey reservoirs during the initial impact. We suspect that the critical factor is the impacted type of peat. Inundation may cause peat matt floatation on sites where a sphagnum peat mantles a relatively undecomposed sedge matt. The consolidated nature of the sedge matt is presumed to provide the required buoyancy for the overlying sphagnum moss. The surface of the raised matt can be expected to be at, or just below, the water surface. The mobility of islands is influenced by the prevailing winds. The frequency of this treed muskeg floatation is expected to decline after the initial impact. This phenomina is discussed under Treed Muskeg With Permafrost, Section 5.4.3.

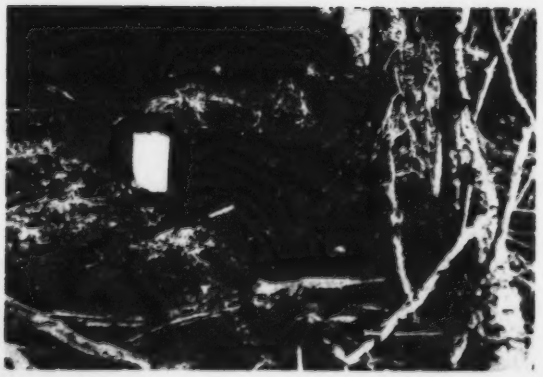


PHOTOGRAPH 62 - Natural State Treed Muskeg Shoreline, Southern Indian Lake. Wave action is undercutting the peat materials causing excessive slumping. The peat and mineral soil is permafrosted. Note the uniformity of the blackspruce stand, typical of permafrosted areas.



SIPIWESK LAKE - A SUNKEN FOREST ON A THAWED PERMAFROSTED SITE.

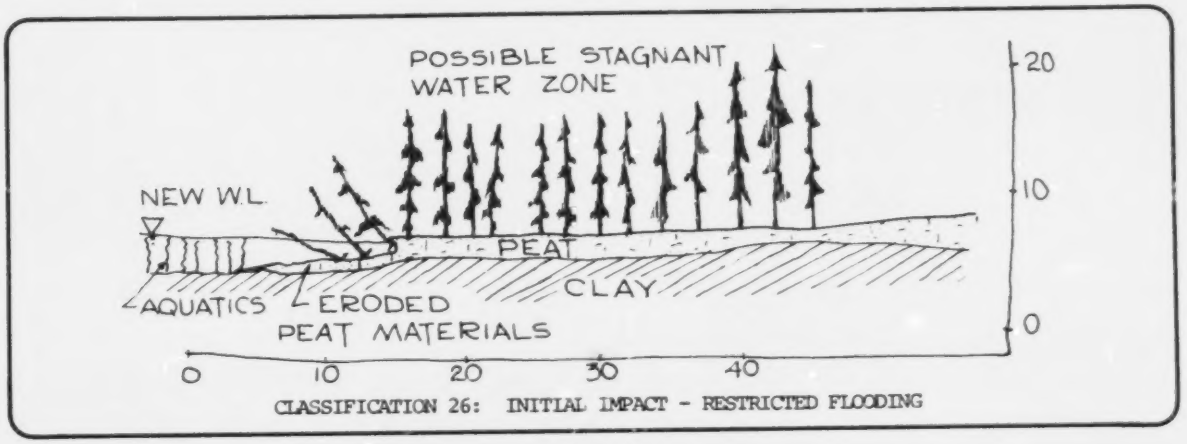
FIGURE 60



PHOTOGRAPH 63 - Sipiwesk Lake, flooded 1960. Water level rise ten feet. This sunken pocket was located at profile site, Figure 60. Liverworts are inhabiting the wet sunken pockets. Moss hummocks are colonized by grasses as the moss dries out.

Initial Impact -

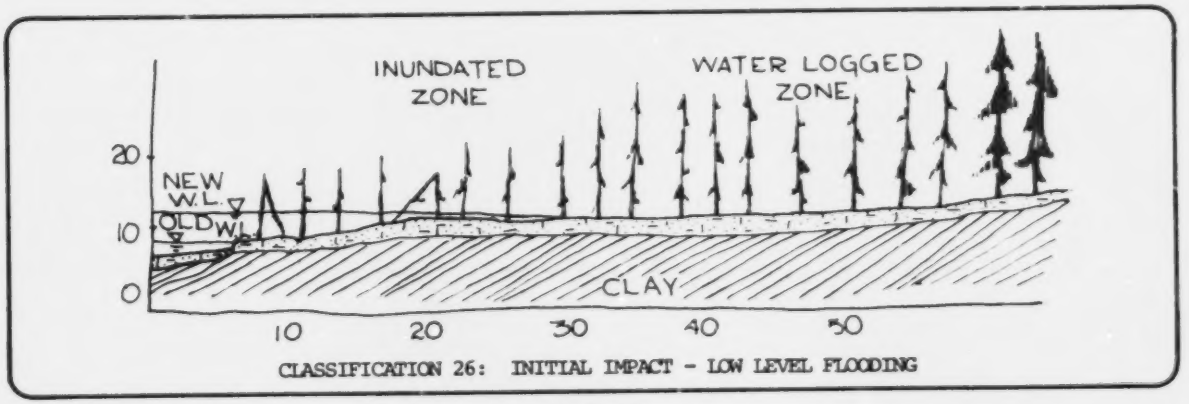
Restricted Flooding: Along most shorelines, the wave action will be increased enough to accelerate shoreline erosion (Figure 61). The peat matt will be undercut and vegetation will slump into the water. As offshore depths are relatively shallow, a considerable amount of debris will accumulate. The levels will not rise enough to create backshore water logging conditions.



CLASSIFICATION 26: INITIAL IMPACT - RESTRICTED FLOODING

FIGURE 61

Low-Level Flooding: The levels will rise above the shoreline into the backshore (Figure 62). In this case, it is assumed that the muskeg will not adjust to the higher water levels. In the event that the muskeg rises slightly with the water levels, erosional processes may occur along the existing shorelines. Initially the wave energy will have little effect on the muskeg as the flooded trees will dissipate the wave action. Backshore water logging will take place in all situations.

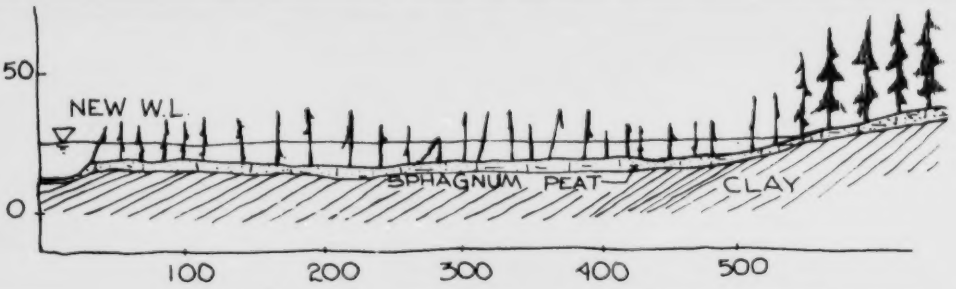


CLASSIFICATION 26: INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 62

High-Level Flooding: Under such conditions extensive stretches of forested area would be inundated (Figure 63). Depending upon the slope, a swath of forest 100 to 1500 feet wide may be inundated. Erosion at the new water-

line will be nil. Little change will take place unless the muskeg becomes buoyant and rises. This will be elaborated upon under "Impact Process Statements For Inundated Terrain", Section 5.4.3.



CLASSIFICATION 26: INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 63

Adjustment Phase -

Restricted Flooding: In this phase, the shoreline will receed until equilibrium is achieved. The concave nature of the shoreline and offshore bench will be instrumental in dissipating the wave energy. Where the backshore does not rise to any appreciable extent and is heavily exposed, this horizontal retreat may still be in process 20 years after the initial flooding. Depending upon the amount of undercutting, a considerable amount of offshore debris may accumulate. The drag created by the tree roots and branches will keep them submerged.

Low-Level Flooding: When the offshore zone of inundated trees is removed, erosion will occur at the water line. Shoreline evolutionary processes will be similar to the restricted flooding case. A water logged backshore zone will be formed, the extent of which will depend upon the muskeg incline.

Within the adjustment phase period, the water logged peat will start to support new shrub and moss growth. The establishment of marsh vegetation will depend upon erosion, offshore materials and edaphic conditions. The occurrence of woody material in the offshore area is not conducive for the establishment of a marsh (Figure 64). Decomposing peat materials may release toxic substances that would inhibit colonization.

CLASSIFICATION 26: ADJUSTMENT PHASE - LOW LEVEL FLOODING

FIGURE 64

High-Level Flooding: In this situation, ice movement and wave action may be responsible for clearing the site of offshore standing trees. The width of dead standing trees is important as this will buffer wave energy before it can affect the shoreline. Where the offshore and interface slope is gradual (in the range of 1 : 10), shoreline erosion has been observed to be negligible after a 13-year period. Such sites appear to have been inundated recently. In general, erosional processes will be greater at headlands than in embayments. After a 15-year period, headlands may not be affected. The slowest recovery rates will be in the sheltered embayments. The horizontal shoreline retreat, common to the Restricted and Low-level flooding, cases, will not be as pronounced in this situation.

The most successful cases of colonization on organic substrate under high-level flooding, is where the forest was either burned or cleared before flooding. Sedges had become sparsely established on cleared organic sites within a three-year period on the Kettle reservoir.

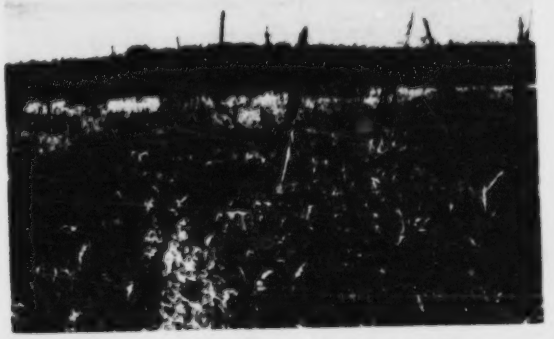
On ideal sites at Kelsey, vegetation was established at the land-water interface after a five-year period. Within the 13th year of post flooding, these shorelines were supporting a five to ten foot zone of sedges with a zone of submerged aquatics in the offshore area. These sites seem to have the potential to develop into a Type 31 shoreline.

Fifty-Year Time Frame -

Restricted Flooding: Within this period a natural state condition will have been achieved and all accelerated erosional processes will have ceased. Acquatic plants may become established on sites where the newly created bottom substrate is suitable.

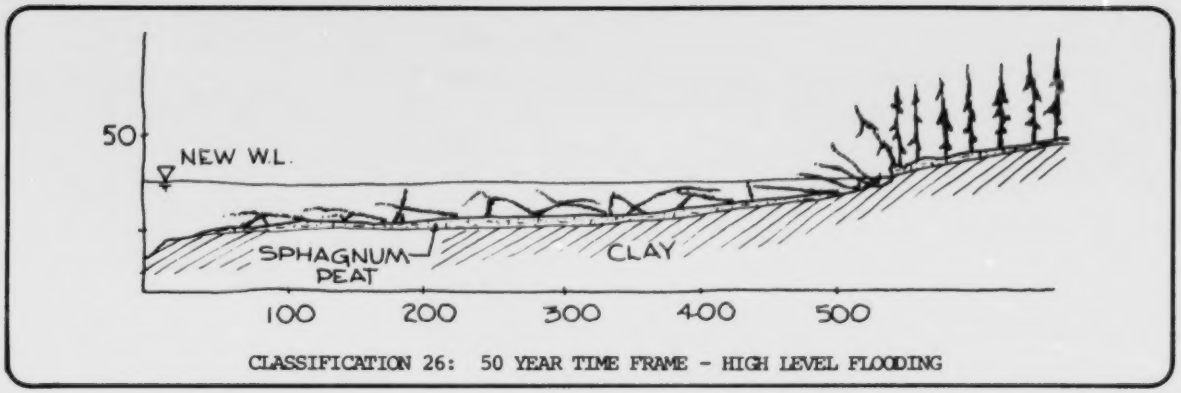
Low-Level Flooding: The concave shorelines should have been formed on exposed sites and all accelerated erosional processes will have ceased. With the retreat of this shoreline a significant amount of offshore debris will have accumulated in the offshore zones.

Marsh colonization processes may be evident along protected shorelines. Along a protected site at Lac Seul, sedges and cattails were growing along the muskeg interface, while willow, alder and tamarack colonization was evident along the saturated backshore (Photograph 64). Black spruce had not begun to colonize the water logged area. Within the backshore open water may still be evident between the higher sphagnum hummocks. The colonization processes will not be as advanced along eroding shorelines.



PHOTOGRAPH 64 - Lac Seul, flooded 1929. Water level rise - ten feet. The effects of backshore waterlogging are evident on this muskeg. Shrubs are slowly becoming established on the higher moss hummocks, while herbaceous species have colonized most of the area.

High-Level Flooding: The shoreline formation processes and ultimate state would be expected to be similar to the low-level flooding case, although the situation would not be as advanced (Figure 65).



CLASSIFICATION 26: 50 YEAR TIME FRAME - HIGH LEVEL FLOODING

FIGURE 65

CLASSIFICATION 27 - LOW SHORELINE IN COARSE SEDIMENTS:

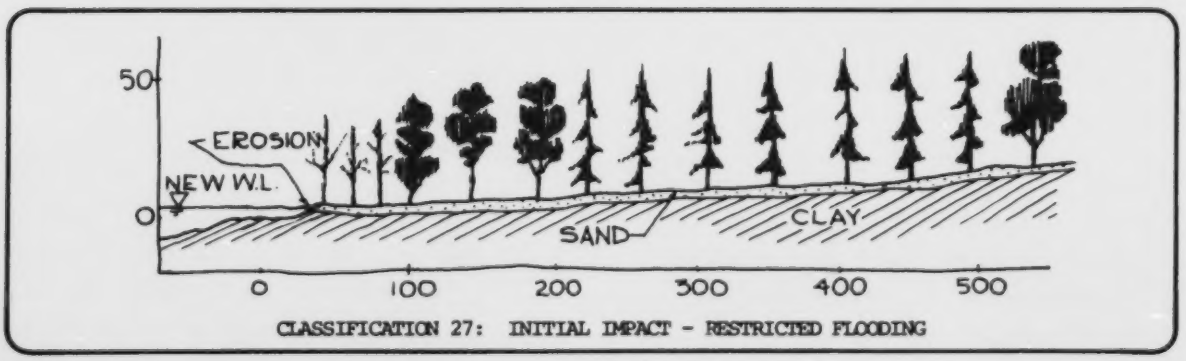
Impact Sensitivity - The low nature of this shoreline makes it extremely vulnerable to flooding. However, due to the reworkability of the materials, it achieves a stable state configuration within a short period after impact.

The new beach formation may not be as extensive as it was under natural conditions where the range of water level fluctuation is greater. A wide water level fluctuation range is conducive to the establishment of a wide beach.

Initial Impact -

Restricted Flooding: The water level rise is within the former shore (Figure 66). The accelerated erosional processes will begin to rework the materials immediately, wave action being the main erosive force. At the water line trees may be uprooted and fall into the water. In the backshore area, a narrow zone of inundated trees will be covered by the reworked sand.

Aquatic vegetation in the offshore zone will likely tolerate the increment.



CLASSIFICATION 27: INITIAL IMPACT - RESTRICTED FLOODING

FIGURE 66

Low-Level Flooding: In this situation, the water will extend farther into the backshore area, inundating a wide swath of forest (Figure 67). The extent of backshore flooding will depend on the slope and water level increment. Erosive forces at the new waterline will be minimal due to the presence of the standing trees. Consequently, no materials will be reworked within this phase.

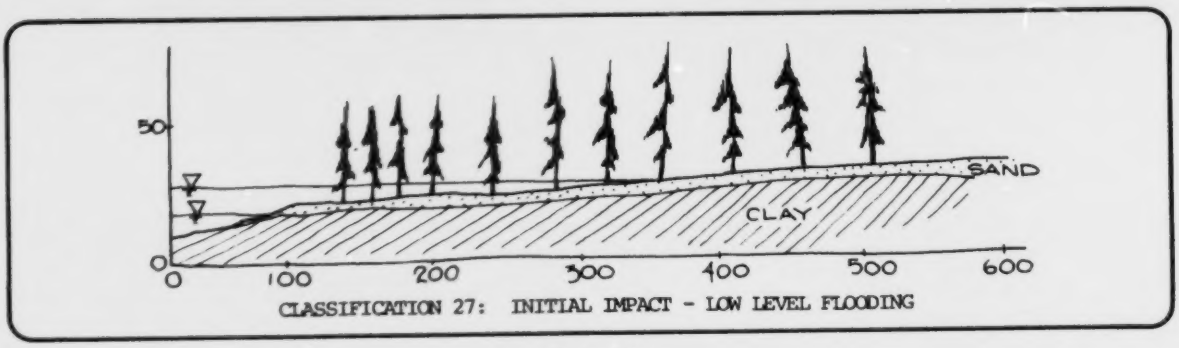


FIGURE 67

High-Level Flooding: Due to the low nature of this shoreline, the water level would rise over the backshore area. Local impacted eskers may act as a source of materials allowing a Type 27 shoreline to evolve. In this case, the processes would be similar to low level flooding situations.

Adjustment Phase -

Restricted Flooding: Wave energy will rework the materials resulting in a horizontal extension of the beach and an offshore bench. This process will be completed within ten years on the majority of wave washed beaches. Along most backshores a narrow swath of inundated timber will still be standing. Normally, the beach will not be heavily cluttered with driftwood. The available driftwood will act as a barrier for sand to accumulate around. The offshore area will contain some detritus. Sites with a mild backshore slope may be colonized by grasses and possibly shrubs (Photograph 65).

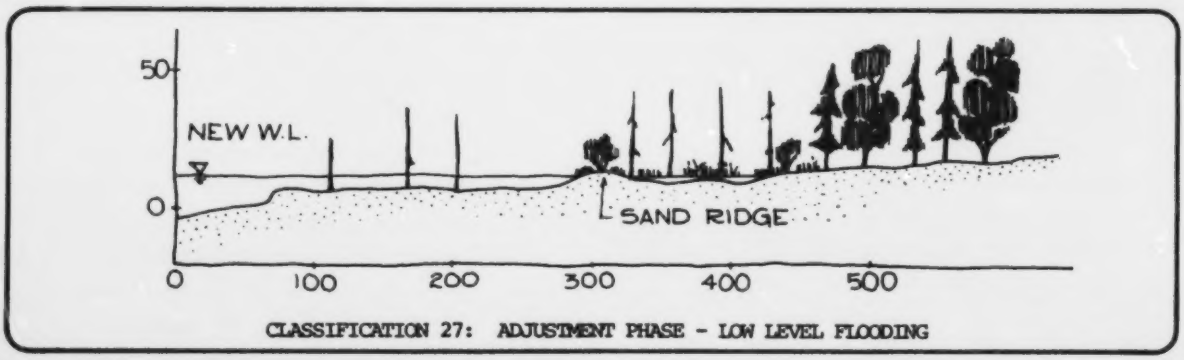
PHOTOGRAPH 65 - Reindeer Lake, flooded 1943. Water level rise - 7.0 feet. Due to the protected nature of this shoreline, wave action is minimal, as a consequence, there is no distinct beach. Grasses inhabited the area once the defoliated spruce allowed the light to reach the forest floor.

Low-Level Flooding: Erosion will commence at the new water line when the majority of offshore standing trees have been removed (Figure 68). Ice and wave action are the major tree removing agents. The beach will be formed near the initial point of contact. When the waves reach the new shoreline, a beach may be formed within 15 years

on exposed sites. These areas can be expected to contain more driftwood and standing trees than restricted flooded areas. The depositional beaches will contain less exposed wood than the reworked beaches. Nearby eskers are an ideal source of materials for beach formation. The driftwood on reworked beaches may act as a barrier for sand to accumulate. Marsh vegetation will colonize shallow water areas where turbulence is minimal, water clarity is high and the substrate is adequate (Photograph 66).

Impacted sites have been investigated where the deposition of sand led to the formation of a beach ridge. These ridges are on low lying land when storm waves wash sand onto the backshore. As the sand is accumulating the colonizing plants are stabilizing this ridge creating a permanent beach landform. As a consequence, the lower backshore area will be poorly drained possibly resulting in the formation of a marsh. Within 20 years sedges and grasses become established in this backshore environment. Shrubs will begin to become established on the stabler moist substrates.

PHOTOGRAPH 66 - Russell Lake, flooded 1952. Water level rise - ten feet. With the lateral recession of this beach, the flooded trees are covered with sand and not knocked down. Marsh vegetation has slowly begun to colonize the offshore area.



CLASSIFICATION 27: ADJUSTMENT PHASE - LOW LEVEL FLOODING

FIGURE 68

Fifty-Year Time Frame -
All Flooding Situations: All accelerated erosional processes will have ceased within fifty years. The sand beach and the bench will be well established in all cases. Dead standing trees will still be on the site but only marginally affecting wave action. The sand may tend to accumulate around wood piled up on the beach (Photograph 67).

The backshore area of beaches will likely contain a narrow fringe of colonizing trees and shrubs. Where a beach ridge has formed the colonization processes should be well under way. Where offshore conditions are suitable a marsh will be present.

PHOTOGRAPH 67 - Lac Seul, flooded 1929. Water level rise - ten feet. Note the lush marsh in the backshore area of the beach ridge. Shrubs are sparcely populating the area indicating drier conditions.

CLASSIFICATION 31 - FEN SHORELINE:
Impact Sensitivity - These shoreline types are dynamic state environments continuously adjusting to the water level fluctuations. The low nature of this landform makes it extremely vulnerable to low and high level flooding. Under these conditions the peat materials are easily eroded and broken down. The impact on a fen in any one area is a function of the total water level increase, the successional stage of the fen at inundation, the seasonal lake level fluctuations, the exposure to wave or current energy and possible ice contact removal during spring break-up. The significance of ice action on these impacted sites is not fully understood. It is expected that ice frozen into these buoyant matts may be instrumental in tearing them away during spring break-up. Moving ice may also be an important relocating factor.

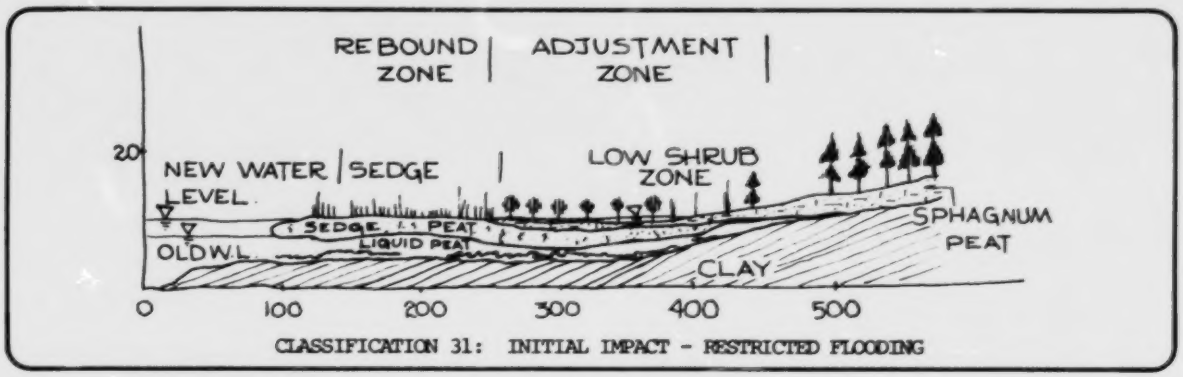
Fen types will vary with regards to species composition, peat type and depth. The type of peat material most conducive to floatation is delt with in "Impact Process Satements for Inundated Terrain - Sedge Communities". In these environments the amount of peat accumulated and subsequent moisture regime dictates the floral zonation, which in turn will be impacted in a different way. A solid floating sedge matt will react to most water level increments by rising with the water surface, while the low shrub and sparcely treed fen areas are slower to adjust but are expected to float. All fen types will not develop to the extent they were before flooding.

Initial Impact -
Restricted Flooding: In this case, the critical erosional force is the ac-

celerated wave energy which may in fact break up the fen periphery. In the majority of cases, the fen will not be adversely effected since fens are located along relatively protected shorelines. Under natural conditions these environments are continually adjusting to a wide range of water level fluctuations.

In the case of a floating fen, the sedge matt periphery is expected to rise with the water level. This will be referred to as the rebound zone. Floating matts will adjust more quickly than matts rooted into overburden materials. The low willow zone is not as resilient as the sedge zone within any fen. The change in moisture regime may not result in shrub mortality. The effects on the backshore treed zone is expected to be minimal, although some water logging may occur.

The marsh zone may not be affected by the new conditions (Figure 69).

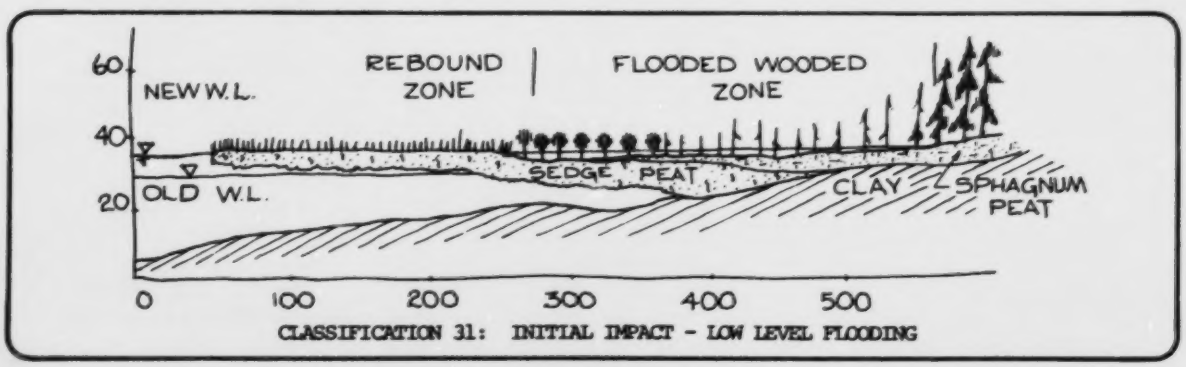


CLASSIFICATION 31: INITIAL IMPACT - RESTRICTED FLOODING

FIGURE 69

Low-Level Flooding: Under these conditions, most fen shorelines are adversely affected. In this case, the increment and subsequent erosive forces, will be responsible for eventually breaking up the fen environment. The sedge matt will rise with the new water surface and the low willow zone will be partially submerged (Figure 70). The extent of the vertical rise of the treed zone will depend up on the thickness and type of peat inundated.

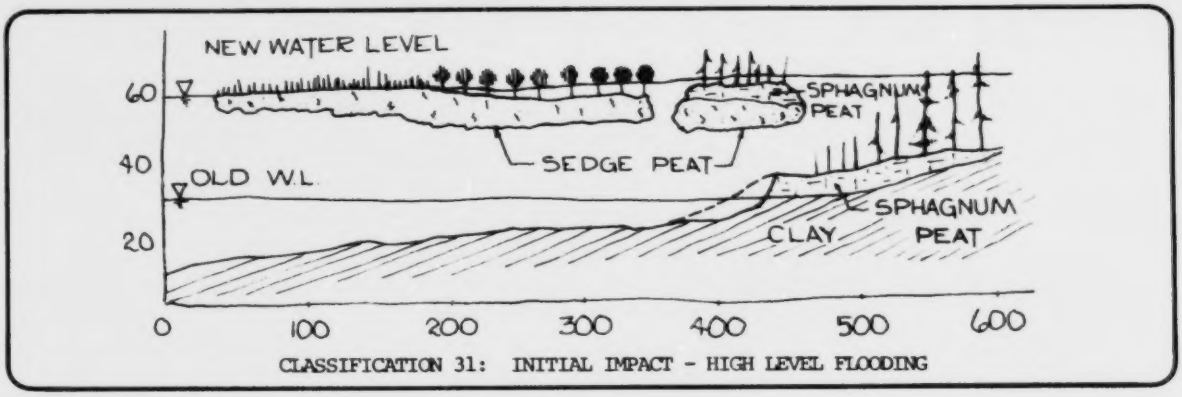
The offshore aquatic vegetation would be totally destroyed.



CLASSIFICATION 31: INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 70

High-Level Flooding: In this case, fens will be most severely impacted. The critical factors being the vertical rise of water surface and exposure to erosive agents. Compared to low level flooding a smaller percentage of the matts will float. The mobility of these floating islands is a function of the wind and/or current action. Entire shrub and tree mortality will occur on these islands (Figure 71).



CLASSIFICATION 31: INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 71

Adjustment Phase -
Restricted Flooding: This phase will be one of community adjustment. The sedge matt zone will continue to grow. The shrub zone, if flooded, may be colonized by sedges or more water tolerant shrubs and the water logged spruce zone may be colonized by tamarack or shrubs.

Sedge matts that are affected by accelerated erosion are expected to erode back until a new equilibrium is reached as the peat body itself can offer little resistance to wave action. The extent of the retreat would be a function of wave energy, backshore slope, and type and depth of organic materials.

Low-Level Flooding: Fen shorelines that are continuously being exposed to wave action would break up during this phase. Impacted fens that are free to move around may collect in nearby concave shorelines. Sedge matts that accumulate within contained and relatively exposed shorelines may form a concave fen shape within 20 years.

The illustration of Sipiwesk Lake, Site A, Figure 73, is an example of an impacted open fen environment. After flooding the sedge matt rose and floated away likely breaking apart shortly after inundation. The underlying substrate acted as a suitable bed for aquatic plant habitation. In contrast to the impacted open fen, the impact on a contained fen environment on Sipiwesk Lake (Site B, Figure 73) was not the same, In this case, the floating sedge matt remained in place. By the 14th year of inundation the majority of the sedge and woody peat had broken down into liquid peat. The low shrub zone along the fen periphery was buoyant and in situ (Photograph 68). It appeared as if the willow root system was binding the suspended peat. These matts are indicated by the decomposed peat matt symbol. In the impacted state, the whole area was bilogically productive, containing a

variety of invertebrate and avian life.

Under a normal or modified flucuation regime, the sedge matts will be expected to rejuvenate on most reservoirs. However, the extreme water fluctuations of eight feet on Sipiwesk are thought to be the main reason for the fen destruction. The water level data available indicated that fluctuations were greater under reservoir conditions than in the pre-flooded state.

As shown in Figure 73, new aquatic vegetation is only sporadically distributed along the old fen shoreline. In most reservoir situations the new vegetative species composition is expected to be totally different from the pre-flooded vegetation. The variation in species is due to the different environmental parameters of water depth, water level fluctuation, water turbulence and clarity, substrate composition, nutrients and oxygen availability. Any one, or a combination of these variables may be critical for the colonization of certain species.

High-Level Flooding: In this case, the majority of the fens will be mobile and exposed to all eroding forces. The chances of a fen accumulating and regenerating along a protected shoreline are less than in the low level flooding case. This is due to the erosive agents and reduced number of floating matts. Since high level flooding usually inundates a great deal of forest, the presence of dead trees will inhibit the sedge matts from reaching protected shorelines. Most fens floating around, will break up early in this phase.

Fifty-Year Time Frame -
All Flooding Situations: By this time most mobile matts will have decomposed. The matts that found their way into shallow protected embayments will be well established (Photograph 69). Open water may still be evident between the matts. Offshore aquatics may be established on the accumulated offshore sediments.

PHOTOGRAPH 68 - Sipiwesk Lake flooded 1960. Water level rise - ten feet. The floating peat matts mark the border of the natural willow fringe on the floating fen. Fourteen years after flooding there was no plant colonization on the floating peat islands. The dead willow roots seem to be the binding force keeping the peat together.

PHOTOGRAPH 69 - Lac Seul, flooded 1929. Water level rise - ten feet. Sedge matts accumulating within a protected shoreline are slowly forming a consolidated fen matt.

IMPACTED FEN SHORELINE

SIPIWISK LAKE - FLOODED 1960

NATURAL STATE ENVIRONMENT 1958

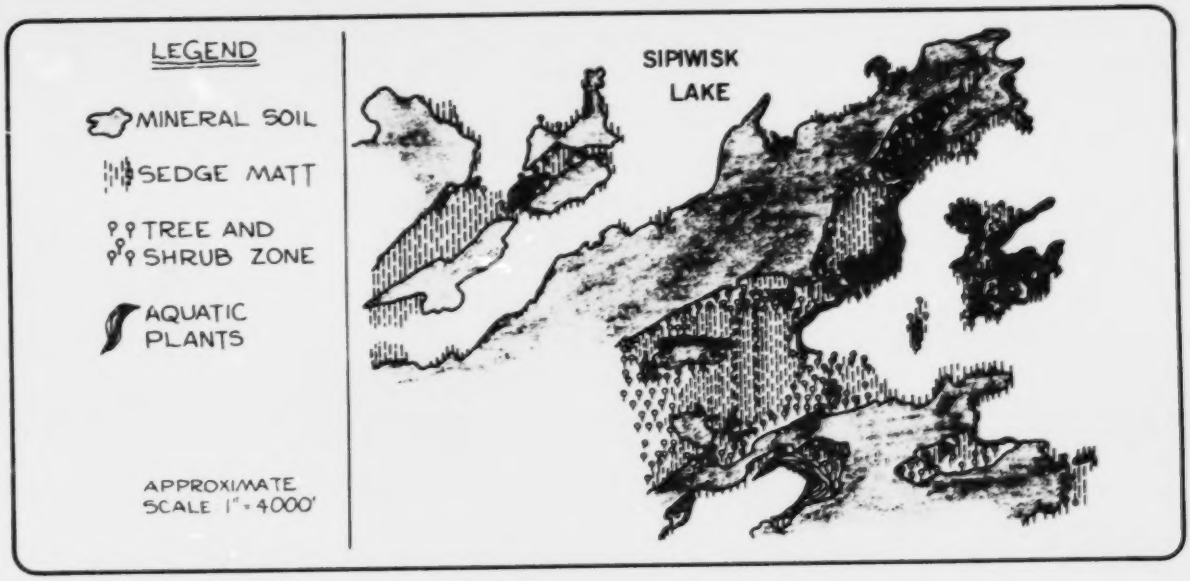


FIGURE 72

IMPACTED ENVIRONMENT - 1974

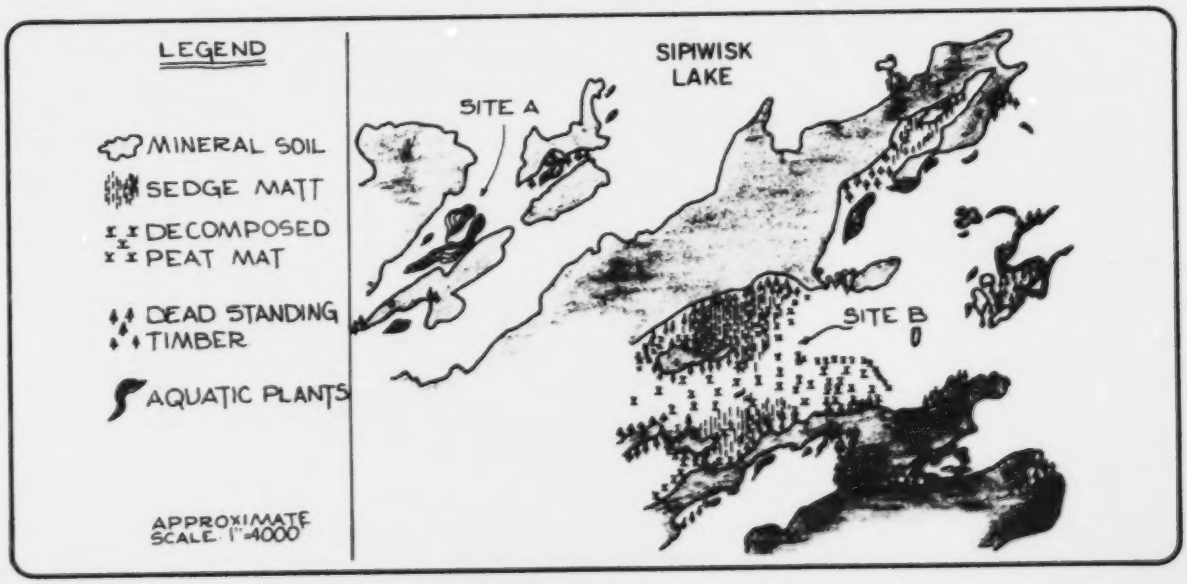


FIGURE 73

5.4.2 IMPACT PROCESS STATEMENTS FOR SHORELINE AREAS -

CLASSIFICATION A - TREED MUSKEG SHORELINE AREA: The type of shoreline that will evolve is largely dependent upon the exposure and the slope of the shore at the new water line. Treed muskeg shorelines (Type 26) may evolve when an erosion scarp is formed. This would likely be achieved within a 50-year time frame as described under high level flooding conditions of an impacted Type 26 shoreline. The most likely alternatives to a Treed Muskeg Shoreline forming on the low slopes seem to be Low Willow (Type 28), Fen Shoreline (Type 31), or possible a Low Alluvial Shoreline (Type 24). Where a granular overburden underlies the Treed Muskeg Shoreline Area, a Low Shoreline in Coarse Sediments (Type 27) may evolve. These evolutionary processes could occur within 50 years as described under low and high level flooding for the Types 28, 31, 24 and 27 shorelines. Due to the depth of overburden and poor exposure, a bedrock controlled shoreline (Types 13, 14 and 15) would not likely be achieved on the Type A shorelines (Figure 25).

Along the new water line, the variables slowing down the formation of a natural state shoreline are the overburden thickness, the low slope gradient, the offshore inundated standing trees and the protected nature of the site. Due to the location of the majority of Type A shoreline areas, the major erosive agent will be wave energy. Current velocities and ice impacts are expected to be minimal.

CLASSIFICATION B - CLAY OVERBURDEN SHORELINE AREA: In this case the type of shoreline that will evolve will depend upon local topography, depth of overburden and exposure. Two type B shorelines have been identified, one typical of the backshore area along the Rat River and one common to the lakes on the Rat River above and including Notigi. In the latter case, bedrock is exposed in the immediate area, while in the former case, the overburden conceals the rock. In both cases the depth of overburden is not known but is assumed to be sufficiently shallow to achieve a bedrock shoreline. The steeper, more exposed slopes, will likely form Bedrock Controlled Shorelines (Types 13B, 14 and 15) within the adjustment phase. The shoreline evolutionary process will be similar to those described under high level flooding conditions for shoreline Types 13B, 14 and 15. If the overburden is sufficiently thick, the shoreline area may evolve into a Clay Shoreline of Moderate Height and Mild Slope (Type 23) or possibly a Shoreline in Slumping Overburden (Type 25) within the adjustment period. The shoreline evolutionary process will be similar to that described under low level flooding for shoreline Types 23 and 25. Due to the moderate slope of the Type B shorelines, it is doubtful that the low-lying shorelines (Types 24, 27, 28 and 31) will be formed.

The ultimate shoreline state and the time required to reach a stable state configuration will vary in each geographical area. In lake situations, the influential erosive force is wave energy while along a river channel, water velocities become important. The exposure to erosive forces will vary depending upon theshoreline configuration. Headlands are affected immediately, while in bays, processes are much slower.

CLASSIFICATION C - ORGANIC TERRAIN IN VALLEYS: Although the lateral flooding range will be extensive, the horizontal rise will be the least of all impacted shorelines. Since the wave energy is negligible within these protected sites, a large majority of the inundated trees will remain standing. In general, the flatter the terrain, the greater will be the number of inundated trees.

These valley type areas are expected to evolve into Fen, Low Willow or Treed Muskeg Shorelines (Types 31, 28 and 26). These shorelines would likely develop within the 50-Year Time Frame. The evolutionary processes will be similar to those discussed under restricted and low level flooding for impacted Types 26, 28 and 31 shorelines. The availability of sedge matts in the area is definitely conducive to the formation of fen shorelines. In certain situations bedrock will form the new shoreline.

CLASSIFICATION D - GLACIAL DRIFT SHORELINE AREA: Along this shoreline area, the ultimate shoreline formation will be a function of the exposure to wave energy, the depth of the drift materials, the composition of the materials and the local topography. In the majority of cases, wave energy will be the only erosional force. Standing offshore trees or floating peat matts can be expected to retard the shoreline erosional processes.

Type D shoreline will normally evolve into a Type 22 shoreline within the adjustment period. The impact would be similar to that discussed under low level flooding in shoreline Type 22. A stable shoreline will be achieved earliest on shoreline areas adjacent to natural lake systems where the wave energy will be the greatest. Under these conditions, a beach will be formed within a 15-year period.

If bedrock underlies the glacial drift at a shallow depth, a bedrock controlled shoreline may be achieved after the drift has been removed.

5.4.3 IMPACT PROCESS STATEMENTS FOR INUNDATED TERRAIN -

CLASSIFICATION - SEDGE COMMUNITIES:

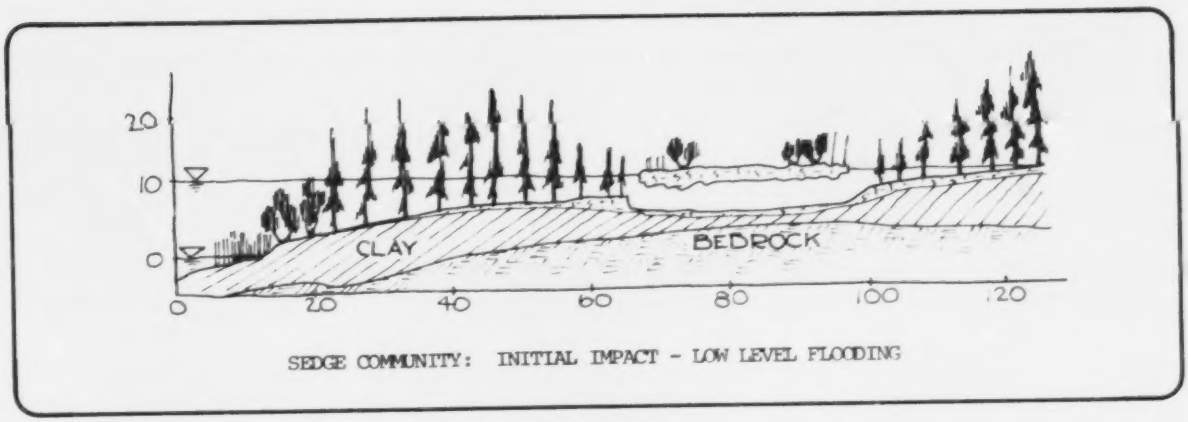
Impact Sensitivity - Sedge communities will be affected only under low and high level flooding conditions. In restricted flooding cases the water may not move into the backshore to affect these communities. Most sedge communities will rise with the increasing water levels. This floatation phenomenon is one of the most interesting and yet poorly understood activities. When discussing such phenomenon a number of criteria have to be considered: the age and peat composition of the matt, the rate of inundation, the total water level rise, the reservoir water level fluctuation, exposure to wave and/or current energy and possible ice contact removal during spring break-up. The type of impact on sedge communities must be considered relative to whether a bog or fen type of environment is involved. The younger successional stages of both peatland types may react in the same manner if all impact criteria are equal.

Upon impact, the age and composition of these communities become important considerations. As peatlands age, the peat accumulates and as a consequence the higher drier surface areas will facilitate moss, shrub and tree growth. With time, a distinct peat layer zonation is evident, Sphagnum peat and forest peat will overlay the sedge peat. The differentiation of peatlands into zones is important as each peat type will be impacted in a different manner. The peat composition of each zone may possibly be used as an indicator of the floatation potential. In a study conducted on peatlands, peat composition was measured on various fen and bog sites (Reference 13). The peat decomposition, as measured by the percent ash content, placed a fen meadow in a 11-25% ash content range, while a wooded fen ash content range is 26-70%. The undecomposed fen peat is definitely conducive to floatation. The proportion of overlying Sphagnum peat to fen peat, or the percent decomposition which is crucial to peat buoyancy is unknown. Actual field observations indicate that heavily shrubbed or treed peat matts will rise when flooded but will not be as buoyant as pure sedge matts. The consolidated sedge matts exhibit a considerable amount of resiliency. On the older maturer landforms the weight and unconsolidated nature of the Sphagnum and forest peat overlying the fen peat may be enough to inhibit total emersion upon flooding.

The rate of inundation and the total increment are the initial forces creating an impact on this environment. Too little is known about the effects on rates of increase water level, but it is suggested that gradual water level rises are more conducive to sedge community floatation than sudden rises.

Initial Impact -

Low Level Flooding: Initially the sedge matts will rise with the new water levels (Figure 74). Due to the low levels of flooding and sheltered positions of the sedge communities, the impacted matts will not move horizontally. If the water level rise was great enough to raise the matts above the dead standing trees, the trailing network of the organic matt would likely create enough drag to restrict matt mobility.

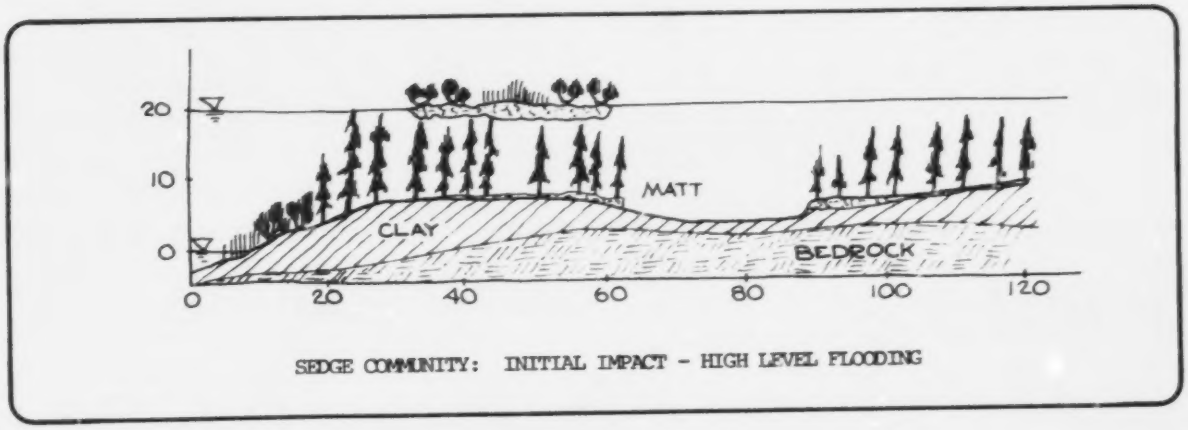


SEDGE COMMUNITY: INITIAL IMPACT - LOW LEVEL FLOODING

FIGURE 74

High Level Flooding: Reservoirs subjected to high level flooding will generate more mobile floating islands than low level flooding (Figure 75). This is largely due to the extent of area inundated by the lateral flooding and the vertical rise of the matts above the standing trees. In this situation, the majority of impacted consolidated sedge matts can be expected to rise with the new water levels. Wind action and currents are the forces responsible for moving these floating islands.

All of the high level flooding cases generating floating islands which were documented were on the Kelsey and Kettle reservoirs. Large central parts of bogs floated up to the Kettle dam shortly after the water level was raised. Although the trees were dead, the matt supported sedge and moss growth.



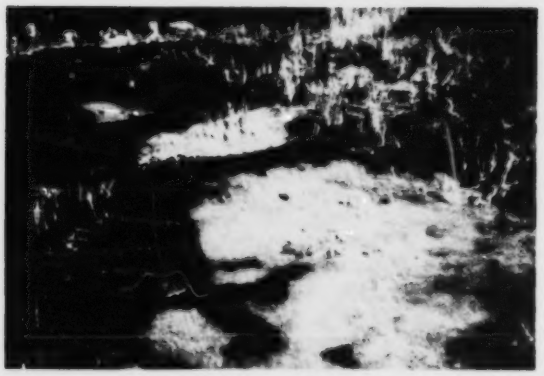
SEDGE COMMUNITY: INITIAL IMPACT - HIGH LEVEL FLOODING

FIGURE 75

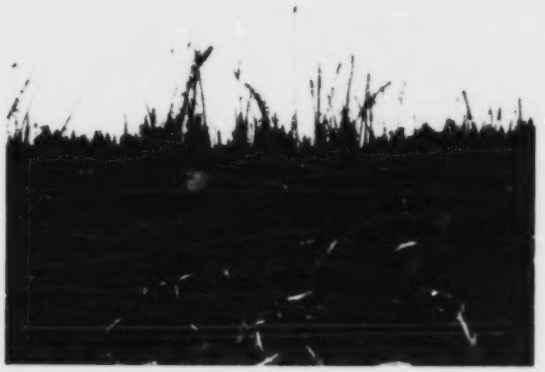
Adjustment Phase -
Low Level Flooding: Plant colonization and subsequently peat accumulation follows low level flooding. The impacted matts will revert back to a younger successional developmental stage supporting new herbaceaus, and water tolerant moss and shrub growth.

In many reservoir situations, bogs that were completely surrounded by open water were observed to begin recovering shortly after flooding. On Russell Lake, a sedge matt was growing and expanding 22 years after inundation (Photograph 70). The flooding was sufficient to cause 100% tree mortality but was not detrimental to the bog matt. The sedge matt will likely form a fen shoreline within 50 years. In protected locations inundated trees can be expected to remain standing for at least 35 years after flooding.

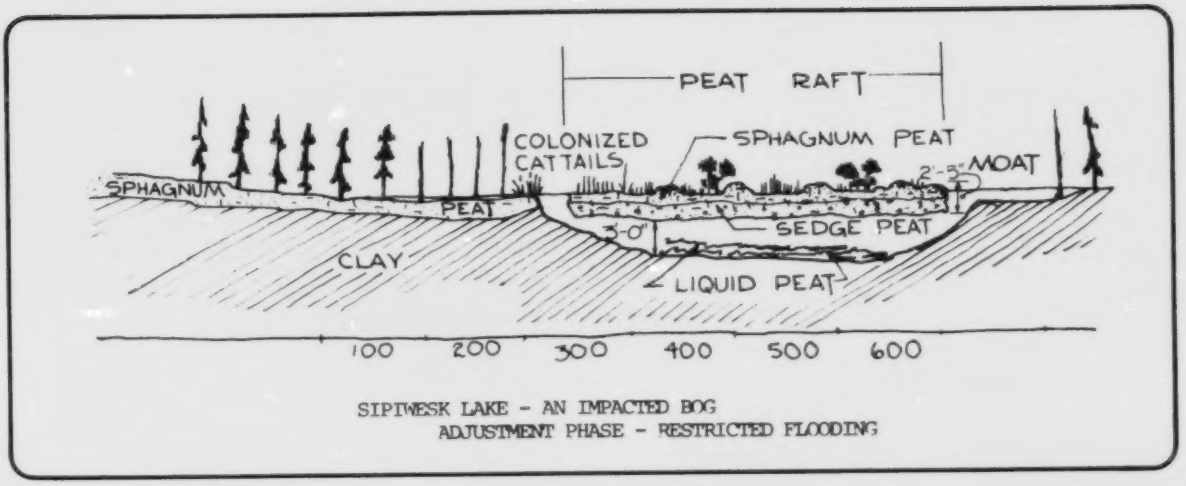
Most bogs subjected to low level flooding recovered. In a site at Sipiwisk Lake, an increment of approximately three to four feet caused the central sedge matt of a bog to rise, breaking away from the surrounding muskeg. Consequently, a moat of open water surrounded the sedge raft. Within 14 years, cattails and other water tolerant species had colonized what had been the open water area. The matt itself was supporting sedge, moss and shrub growth. The two and a half-foot thick raft was floating above three feet of liquid peat (Figure 76). A swath of spruce approximately 100 feet wide around the sedge matt was killed by flooding (Photograph 71).



PHOTOGRAPH 70 - Russell Lake, flooded 1952. Water level rise-ten feet. The water level increment was insufficient to relocate the matt. The inundated standing trees would not have restricted mobility under high level flooding situations. The sedge matt is expanding and will likely form a Fen Shoreline within this embayment.



PHOTOGRAPH 71 - Sipiwesk Lake, flooded 1960. Water level rise-eight feet. This bog was elevated a few feet while the adjacent treed muskeg stayed at its original level. The surrounding swath of trees was inundated.



SIPIWESK LAKE - AN IMPACTED BOG
ADJUSTMENT PHASE - RESTRICTED FLOODING

FIGURE 76

High Level Flooding: During this phase, the number of floating sedge matts in a reservoir will gradually decline. The larger matts are susceptible to most erosive agents and if they do not move into a sheltered embayment soon after rising, they break up and sink. Floating matts that find their way into shallow protected sites may regenerate and form the new shoreline. This is how some fen shorelines were formed in Lac Seul under low level flooding.

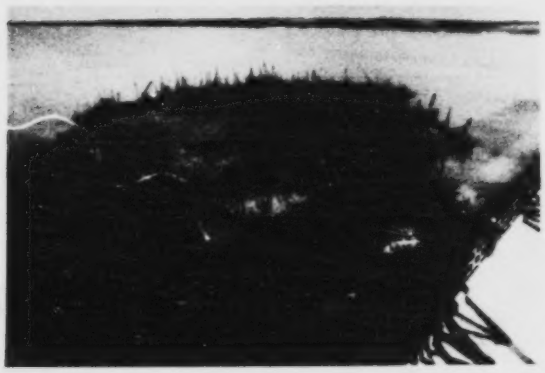
Four years after the Kettle reservoir was formed, the number of large floating islands had diminished although there were still numerous small floating islands in the reservoir. Many were supporting living vegetation (Photograph 72 and 73).

50 Year Time Frame -
Low Level Flooding: All colonization processes should be well advanced within fifty years. Some matts may be supporting shrub growth where the peat is thick but it is unlikely that these sites will be treed. Aquatic plants may be growing in the offshore area where the environmental conditions are favourable.

High Level Flooding: Under certain conditions, reservoirs may continue to generate floating sedge matts. This is a phenomenon common to areas where there are extensive sedge communities in the reservoir backshore. The Great Falls dam on the Winnipeg River, which has been in place since 1922, is still generating floating sedge matts. According to Hydro personnel a natural constriction in the reservoir channel causes water to back up into peatland bays during periods of high river flow. This condition presumably is enough to dislodge the matts. Once detached, south easterly winds guide the matts to the dam site. Islands floating up to the dam have been observed to be 300 feet by 100 feet in dimension, and some matts support willow growth but very few are treed. These matts are believed to be of a fen origin. Ice action is an instrumental force in dislodging sedge matts under both reservoir and natural conditions. Ice lodged in the matts may pull sections away from the main body during spring break up.

Sedge matt floatation is not entirely reserved to reservoir situations. Float-

ing sedge matts can be seen on natural water systems. The more southern lakes in the province seem to be more conducive to sedge matt propagation. This is in all likelihood due to the more favourable climatic conditions.



PHOTOGRAPH 72 - Kettle Reservoir, flooded 1970. Water level rise - less than 98 feet. This large central section of a bog floated to the dam site the year after the reservoir was formed. These matts broke up as they entered the sluice gates.

PHOTOGRAPH 73 - Kettle Reservoir, flooded 1970. Water level rise - less than 98 feet. Sedge islands are still floating in the reservoir four years after flooding. This bog matt has adjusted to the new moisture regime and is supporting living vegetation.

CLASSIFICATION - TREED MUSKEG TERRAIN AND TREED MUSKEG TERRAIN WITH PERMAFROST:
Impact Sensitivity - Tree islands have been observed floating in reservoirs created under high level flooding conditions. Less is known about treed island floatation than sedge community floatation. It is expected that the lower sections of these islands are composed of sedge peat, as pure Sphagnum matts may not be sufficiently buoyant enough to rise or consolidated enough to stay together.

Initial Impact -
High Level Flooding: Treed matts that are going to rise will do so when the reservoir is first formed. A reservoir will not continue to produce treed islands. Floating matts densely populated with black spruce were observed on both the Kettle and Kelsey reservoirs during the initial impact. According to a Hydro official at the Kettle site, treed muskeg matts rose off rock outcroppings as the Kettle forebay was formed. The depth of the islands varied from approximately four to ten feet. Some of the islands contained permafrost. The larger islands were one to one and a half acres in size with spruce trees 10 to 15 feet high.

It is interesting that some of the floating islands were frozen. This may have been permafrost or a seasonal frost. At this time, the relationship between treed island phenomenon and permafrosted organic soil is unknown. The ice itself may be providing the required buoyancy. If this is the case, the islands would sink once the frozen core thawed. This seems to be what happened to many of the floating treed islands.

Another interesting phenomenon at the Kettle site was the seasonal sinking and rising of treed islands. Floating mobile islands were observed to sink in the latter part of the first season of forebay formation, only to rise in the following season. One hypothesis is that the formation of gases in the warm summer water (65°F) resulted in their buoyancy. The following summer they sank and did not rise again.

Adjustment Phase -
High Level Flooding: Treed island floatation is a short term phenomenon. By the sixth year the majority of these islands will have sunk. Midway through this phase there will be no floating treed islands. Such islands sink in situ shortly after rising, or become mobile and possible collect at the dam site, or remain floating in situ within some protected embayment. But even after they loose their buoyancy, their presence is important as they will undoubtedly influence the colonization processes that are to follow in shallow water sites.

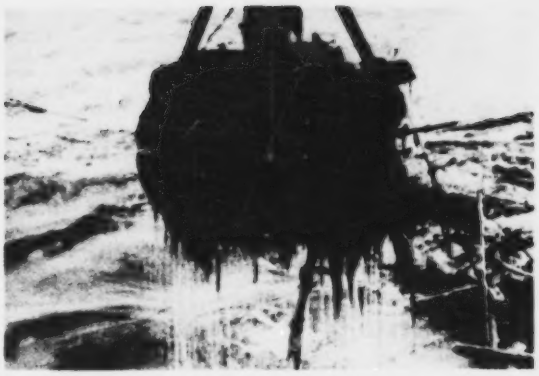
In the Kettle site, treed islands were still mobile four years after the reservoir was formed. However, they were splitting apart and were not supporting any plant life (Photograph 74).

On the Kelsey reservoir, islands 400 feet by 500 feet across were still held together five years after flooding. These islands were confined in a sheltered area. The matts will be a suitable substrate for colonization by fen species.

Islands floating up to the dam sites are normally broken up and fed through the spill gates. During the early years of reservoir formation, a considerable

amount of organic debris can be expected to accumulate at the dam site (Photograph 75). The extent of the debris is largely a function of the degree of flooding, the type of terrain inundated and forces to move the islands. The effects of this material on the water quality down stream is unknown. Although the occurrence and release of these organic materials is a short term phenomenon, the sedimentation of such material down stream will undoubtedly have long-term implications.

During this phase, the floating islands are a reservoir management problem.



PHOTOGRAPH 75 - Kettle Reservoir dam site. During the first years of forebay formation, a considerable amount of organic matter can be expected to collect at the dam site.

PHOTOGRAPH 74 - Kettle Reservoir, flooded 1970. Water level rise less than 98 feet. These treed islands may have originated from bog sites, but because of the presence of standing trees are classified as treed muskeg. After four years of floating, they are supporting no living vegetation and slowly breaking apart.

CLASSIFICATION - CLAY OVERBURDEN - GLACIAL DRIFT - BEDROCK OUTCROP:
Impact Sensitivity - As "Inundated Terrain" the overburden and plant cover is submerged, however, the type of substrate is important in determining the length of time the trees will remain standing. The removal of inundated tree species is to a large extent dependent upon wave action, current and ice movement.

From the research on reservoirs, it became apparent that certain flooded tree species remained standing longer than others. The variation being likely due to the difference in rooting systems or resistance to rotting agents. Consequently, we have concluded that coniferous trees will remain standing longer than deciduous trees under flooded situations.

Aspen, poplar and birch that remain standing will often break off at the high water mark while spruce trunks would remain in tact for a longer period of time.

Although all trees have various tolerance limits to flooding and consequently different dying rates (Reference 14), two years of continuous flooding is detrimental to the trees. Tree mortality will occur in the first two to four year period. However, the entire root crown must be totally inundated to cause immediate mortality. Moreover, as long as the root crown is completely covered, the depth of overlying water is of little consequence.

Studies of inundated trees have shown that several tree species will put down normal annual increments after temporary flooding, but when death comes, it is sudden (Reference 14). Similar type studies at Sipiwesk Lake have shown that this may also be true for white spruce.

Treed areas periodically inundated at Sipiwesk have clearly shown the different dying rate between the aspen, poplar willow, jack pine and white spruce. Repeated observations proved conclusively that the dead line for hardwood species was always lower on the slope than that of the conifers (Reference 15).

Initial Impact -
Low and High Level Flooding: All trees not subjected to ice movements, currents or wave action will remain in situ held by the extensive root systems. Trees rooted in bedrock may be the most stable as shown in Photograph 76.

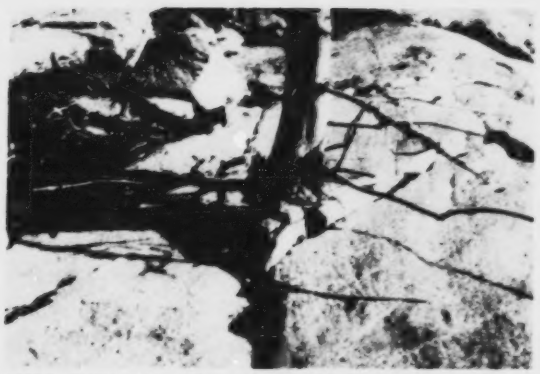
Adjustment Phase -
Low and High Level Flooding: Beyond the initial impact, the flooded trees would be somewhat more susceptible to eroding agents. Mortality will reduce the holding strength of the vast network of small roots and rootlets, thereby increasing the possibility of the tree being removed.

Rotting of the trunks some two feet above the water level weakens the trees at this point causing the tree to break when wind action is significant. In areas sheltered from wind, trees were noted to stand over a much longer period of time (Photograph 77).

Indications at Kettle and Kelsey reservoirs, both high level flooding situations, are that trees exposed to fluctuating ice levels will gradually be knocked down within the early portions of this phase (Photograph 78). The extent of the re-

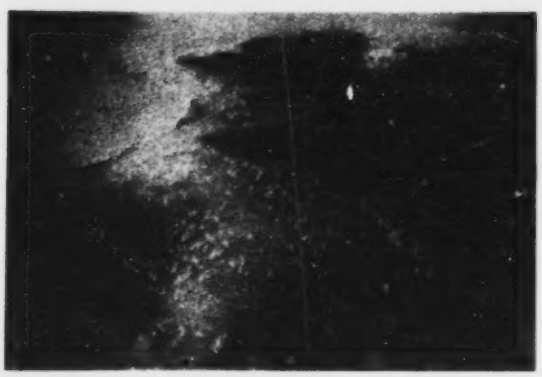
moval is at times difficult to ascertain without knowing exactly what was present in the pre-flooded state.

Fifty-Year Time Frame -
High Level Flooding: Inundated trees will still be evident along protected embayments. Such trees seem to last indefinitely. Although wave action is negligible, wind may be one of the main forces responsible for tree removal in the protected sites. Trees that have their root systems wedged in bedrock materials remain standing for indefinite periods (Photograph 79).



PHOTOGRAPH 76 - The root system of the tree wedged in bedrock crevices. Although the organic soil has been removed, the tree is in situ and will likely remain standing until the wedged root system gives way.

PHOTOGRAPH 77 - Sipiwesk Lake, flooded 1960. Water level rise - eight feet. After 13 years of flooding, a few trees have been knocked down. This particular site was not entirely protected from wave action.



PHOTOGRAPH 78 - Kettle Reservoir, flooded 1970. Water level rise - less than 98 feet. After three years of flooding, many of the trees are at an incline. The rate of removal can be attributed to the manipulation of ice levels by Hydro. High ice levels were purposely lowered throughout the winter in an attempt to eliminate the majority of standing dead trees.

PHOTOGRAPH 79 - Lac Suel, flooded 1929. Water level rise - ten feet. Trees exposed to wave action still remain standing, though most have broken off above the water lines.

5.4.4 IMPACT PROCESS STATEMENTS FOR RIVER CHANNELS WITH INCREASED FLOW -

GENERAL DISCUSSION: Stream currents and ice movement are the most significant factors in anticipated adjustment processes along river channels in the study area. These factors will be instrumental in erosion processes and clearing of vegetation in areas where currents are significant.

In reaches where the present channel shape and size is determined by the present discharge regime, changes in channel shape and size will be required. Erosion to a stable configuration will occur. In simple terms, the major change will be erosion of the stream bed as the hydraulic forces on it are increased, accompanied by erosion of channel banks as the stream adjusts in width.

In areas where the stream channel is wider and currents are smaller, less erosion will occur. Most trees subjected to fast flows will be removed within the first few years of flooding. The current will deposit the debris in sheltered areas or in the various lakes along the river.

The effect of ice along these channels is a special consideration. Along the Rat-Burntwood River system below Notigi, and in the lower reaches of the Nelson River, highest levels will occur during the winter with the formation of an ice cover. This will result in a zone above the summer level which is annually flooded during the winter.

While erosion in this zone under the ice cover is not expected to be as rapid as under summer levels, ice forces and movements will result in damage to trees. As this is the dormant season for vegetation, trees in this zone will probably not die by flooding for many years. Some scouring of the shoreline in this zone will occur, along with the crushing of smaller shrubs as levels decline in the spring and ice remnants drop. Ice movements during breakup are a major consideration in removal of dead trees under summer water levels and living trees in the ice-cover zone.

Effects of summer flooding and wave action have been discussed under "Impact Process Statements for Shorelines" for various depths of flooding. Wave action will be a secondary consideration along most narrow sections.

Table 6 summarizes the occurrence of the various shoreline types in areas along river channels where currents are an important consideration. Impact statements are made for channel sections where the discharge is increased. The statements concentrate on the processes that are peculiar to river channels. In most cases the river impact will be similar to the lake shore impact. The Lower Churchill River case, with lower discharges, will not be considered here, but will be discussed in the detailed Churchill River impact evaluation.

TABLE 6

APPROXIMATE RIVERSHORE

DISTANCES IN MILES

Classification	11	12	13	14	15	21	22	23	24	25	26	27	28	31
River System														
Rat	1		51	37				26					43	
Burntwood (Diversion route)	2		24	72				41		16			10	
Lower Churchill	17	22	51	46		196	25	18	45	29			11	22
Upper Nelson	24		136	65	114		2		1		41	26	18	
Lower Nelson		26	45	6		105				66			4	

CLASSIFICATION 11 - STEEP BEDROCK SHORELINE: Along this shoreline, as is the case with many of the other channel shorelines, the impact is considered under both summer and winter water levels. The channel impact under summer conditions is identical to that described under impacted lakeshores. Where a winter surcharge in ice levels occurs, most organic soil and overlying vegetation will be removed in the ice surcharge zone early in the adjustment period. Although this ice action may not remove the trees wedged into the rock immediately, it will ultimately kill the trees. These trees will not likely be removed as quickly as the trees effected by the summer flows. The trees left standing in this zone are not significant due to the sparce distribution. The river channels are expected to clear themselves of trees faster than the lakeshores.

CLASSIFICATION 12 - VERTICAL BEDROCK SHORELINE: The impact has already been adequately described in the preceeding section under "Impact Process Statements for Shorelines", Section 5.4.1.

CLASSIFICATION 13A - LOW BEDROCK SHORELINE WITH SHALLOW BACKSHORE OVERBURDEN: Due to the mild slope and plant cover at the new water line, the affects of the winter surcharge phenomenon will be greater along the mild sloping shorelines than along the Steep and Vertical Bedrock Shorelines. The swath of flooded forest created when water levels are raised will initially have the effect of protecting the winter surcharge zone from moving ice at spring break-up. The removal of the trees is a function of the substrate the trees are rooted in and the strength of the erosive forces. As along lakeshores, trees rooted in organic soil will be removed faster than those wedged in bedrock fractures. The channel clearing will be completed first on sites exposed to moving ice and high velocities. Most river channels will be cleared faster than their lakeshore counterparts.

When the offshore trees are removed, erosion at the surcharge zone will occur, but will be limited due to the presence of the border ice cover. The sites exposed to ice movements will be cleared of trees in the ice surcharge zone early in the adjustment phase, while the processes will be much slower along protected shorelines. On sites subjected to lesser currents, a band of border ice will be firmly anchored to the tree trunks in the winter surcharge zone. This is the case when the water levels drop before the sheet of hanging ice melts or breaks up. As water levels drop following breakup, the border ice remnants will drop, removing bark from tree trunks and crushing the ground cover. As a consequence, the majority of the vegetation will be killed in the surcharge zone within a four year period. The physical scraping of ice on bark will ultimately kill the trees.

Figure 77 illustrates the effect of ice surcharge on vegetation.

The effects of the winter ice surcharge will create a swath of dead standing trees bordering the summer water level. The width of the swath is a function of the slope above the water line and the vertical ice surcharge.

Surcharge zones exposed to moving ice may be cleared of standing dead trees within a 15 year period. This will vary depending on the ice conditions. The exposed sites will contain less fallen debris than protected sites where mobility will be restricted within this ice surcharge zone. The annual repetition of this phenomenon will inhibit colonization process within this zone, regardless of the substrate. Grasses or possibly sedges will constitute the majority of the surcharge zone vegetation where a mineral soil exists.

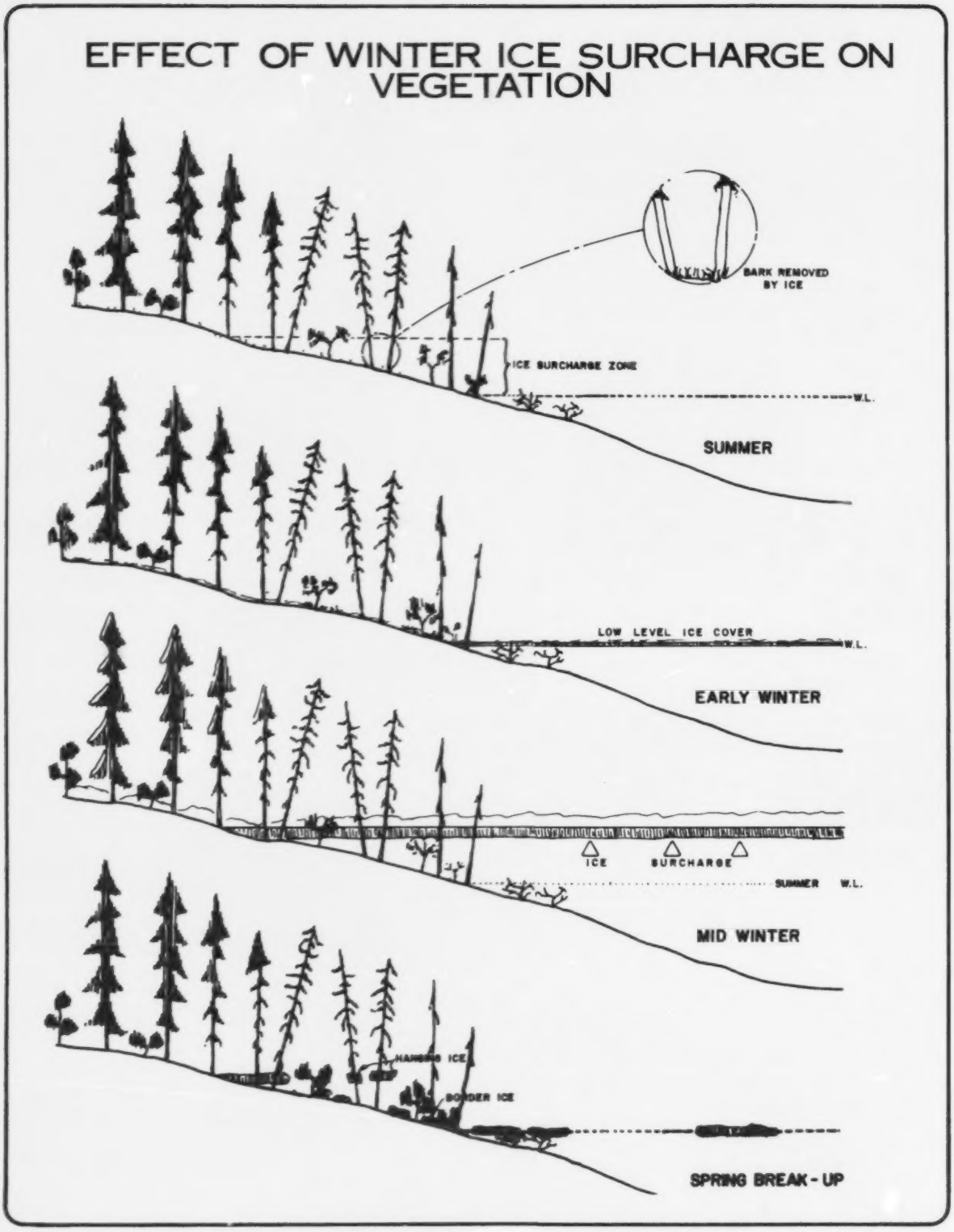

EFFECT OF WINTER ICE SURCHARGE ON VEGETATION
BARK REMOVED BY ICE
ICE SURCHARGE ZONE
W.L.
SUMMER
LOW LEVEL ICE COVER
W.L.
EARLY WINTER
ICE
SURCHARGE
SUMMER W.L.
MID WINTER
BORDER ICE
SPRING BREAK - UP

FIGURE 77

CLASSIFICATION 13B - LOW BEDROCK SHORELINE WITH DEEP BACKSHORE OVERBURDEN: As in Type 13A these shorelines are generally well exposed to river currents; however, Type 13B will be subject to bank erosion and slumping. Initially the erosion rates may be in excess of one foot per year, but this will largely depend upon the current. Erosion of the channel bed and bank is expected as the channel adjusts in shape to the increased discharges. This will occur at progressively lesser rates as channel adjustment takes place and currents reduce. The overburden will be eroded until bedrock is reached. The rate will vary depending on the current, the depth of overburden and the slope. As the overburden is eroded the undercut vegetation will be washed downstream.

The flooded vegetation will initially offer some protection from the currents. The majority of flooded trees will likely be removed on exposed shorelines within the early part of the adjustment period.

Most trees, except those in the sheltered areas, will be removed within a five to ten year period.

The winter surcharge zone in Type 13B will not extend as far laterally into the backshore as in a Type 13A shoreline due to the greater height of the clay bank. Bank colonization processes will be very slow due to unstable bank conditions. Even after the channel erosion has progressed to and been halted by bedrock at the open water level, the winter surcharge will extend to the overburden above the bedrock continuing bank erosion.

CLASSIFICATION 14 - BEDROCK CONTROLLED SHORELINE WITH OVERBURDEN BEACH: The protected concave configuration of this shoreline will minimize the clearing of inundated trees. A larger percentage of trees will be removed from the channel than would be in the lake situation due to the high velocities and ice movement within the channel.

Initially bed and bank erosion will be inhibited by the present tree and shrub cover, resulting in slower velocities along the shore. Velocities will increase as the outer fringe of trees is removed. Some of these shorelines will tend to accumulate trees removed from upstream portions of the channel thereby cluttering the area with more debris. Bed erosion in the summer flooded zone will result in the eventual weakening of tree support. Early in the adjustment phase these trees will either be carried downstream by currents and ice movement or be pushed further into the congested embayment. This largely depends on the configuration of the shoreline and the directional movement of the water and ice.

The winter surcharge effects will be similar to those described. The dead tree zone created by winter ice levels will not be cleared as is anticipated along headland shorelines.

CLASSIFICATION 15 - LOW BEDROCK CONTROLLED SHORELINE: In this case, the shoreline processes, both erosional and winter surcharge, will be similar to those described under Type 13B. As these shorelines are not as exposed to erosional forces as are the headland shorelines, the processes will be slightly slower.

CLASSIFICATION 21 - ICE SCOURED TILL BANK: The impact on this shoreline has been discussed in the preceeding section under "Impact Process Statements for Shorelines", Section 5.4.1.

CLASSIFICATION 22 - SHORELINE IN COARSE SEDIMENTS: Shorelines of this type occurring along main river channels exist primarily in the Lower Churchill river system. These sites will be subjected to lower water levels.

CLASSIFICATION 23 - CLAY SHORELINE OF MODERATE HEIGHT AND MILD SLOPE: The impact along this channel shoreline was described in the preceeding section under "Impact Process Statements for Shorelines", Section 5.4.1. Of special concern is the ice surcharge that is anticipated along certain rivers within the study area. As these shorelines are generally exposed to slower currents than the Type 13 shorelines, the removal of dead trees within the surcharge zone will be a prolonged process. The ice flows will likely remove the majority of trees in the surcharge zone within 30 years.

CLASSIFICATION 24 - LOW ALLUVIAL SHORELINE: Impacts and processes will be restricted to flooding of vegetation and will be the same as lake situations of similar water level regimes. These sites will be areas of increased deposition following flooding but it is doubtful that accumulation of debris will be sufficient to be significant.

Shorelines of this type where stream velocities are significant are restricted in the study area of Cross Lake and to stretches totalling one mile along the channel below Cross Lake. These sites will be exposed to generally lower summer levels and occasional higher summer peaks. Little effect is expected on vegetation on the Cross Lake shoreline. Rising ice levels in early winter may remove some willows, but this effect will be limited because future peak winter levels will only be marginally higher than present summer mean levels. These sites being still-water areas, will be zones of driftwood accumulation.

CLASSIFICATION 25 - SLUMPING OVERBURDEN SHORELINE: These sites occur at areas of erosion along stream channels, generally occurring at river bends and in meanders which are exposed to the full force of the river flow. Increased discharge and water levels, together with thawing permafrost will initially accelerate erosion by undercutting the base of the bank. Currents will remove trees soon after they slump into the stream; protection from this source will therefore, be minimal. Ultimately, bank erosion will reduce to pre-diversion rates as the channel widens. A return to pre-flooding conditions will occur within the fifty year period.

CLASSIFICATION 26 - TREED MUSKEG AND 27 - LOW SHORELINE IN COARSE SEDIMENTS: Under higher discharges and levels these two shorelines are identified only in the Upper Nelson system, occurring in slower current areas. Additional regulation will result in even lower velocities at most sites. Consequently, effects of currents may be ignored, and impacts will be as in lake situations.

CLASSIFICATION 28 - LOW WILLOWED SHORELINE: These shorelines occur in embayments and low areas where stream currents are minimal. Impacts will be limited to wave action and flooding. Embayments of this type will be subject to deposition of suspended soils and driftwood from the main stream.

Early-winter rises in ice levels in the ice levels in the Burntwood River will be important in the removal of summer-flooded willows within the first few years. The zone of ice surcharge itself will be high enough above the present water levels (greater than ten feet) to be above the low shrub zone. Ice level fluctuations in this zone will result in tree damage and removal within ten to twenty years. Recolonization in this zone is expected to be by grasses and shrubs.

CLASSIFICATION 31 - FEN SHORELINE: This shoreline type does not occur along any channels or in any areas of winter surcharge along the Rat-Burntwood System, but does occur in the estuary of the Churchill River at Hudson Bay.

6.0 OBSERVATIONS AND CONCLUSIONS

6.1 CHURCHILL RIVER DIVERSION, RAT-BURNTWOOD RIVER SYSTEM

6.1.1 GENERAL DESCRIPTION OF THE RAT-BURNTWOOD SYSTEM: The headwaters of the Burntwood River lie in the tributaries to Burntwood Lake over the height-of-land from Flatrock Lake on the Churchill River. The Rat River also rises at the boundary of the Churchill watershed near Issett Lake. The Rat which joins the Burntwood in Three-point Lake is well over 100 miles in length and drains an area of 2,530 square miles. Its computed average annual flow is 1,020 cfs. The Burntwood, meanwhile, including the Rat River, has an average annual flow of about 4,000 cfs. at the mouth, draining an area of 9,870 square miles.

In the extreme upper reaches of both rivers, the flow is docile. Here the river streches are simply narrow connections between lakes. Segments of the Burntwood and the lower end of the Rat have frequent rapids and falls. With the exception of the extreme upper ends, the flow is controlled by bedrock, at least vertical control. Horizontal control is most frequently alluvial with bedrock showing itself mainly on the lakes or at rapids in the river.

Throughout these watersheds the underlying geology is granites and gneisses originating in the Precambrian.

The bedrock, up to about 1,000 feet above Mean Sea Level, is covered by a heavy layer of lacustrine sediments. Deposited on the bed of Lake Agassiz, clay, silt and occasional sand sediments effectively mask contour details of the underlying geologic formations. As a result, outcrops are not frequent except for these ridges of elevation greater than 1,000 feet. The lower third of the Burntwood flows through generally heavier deposits and continuing erosion is evidence of the remaining instability of certain shorelines.

The Rat-Burntwood system does not possess the grandeur of the Churchill or Nelson Rivers. Nonetheless, the beauty of its lakes, its rapids and falls make it no less attractive than the others.

6.2 CHURCHILL RIVER DIVERSION - SOUTH BAY TO NOTIGI

6.2.1 Natural State Conditions - South Bay to Notigi: This portion of the Rat River drainage system, encompassing the river itself from Issett Lake to Notigi, the adjoining lakes and major inflowing river systems will be referred to as the Notigi Reservoir, as shown in Figure 78.

Lying within the Precambrian rock belt, the area transversed by the Rat generally consists of exposed bedrock or is bedrock controlled. The variety and structural composition of the bedrock varies within the reservoir. Predominant rock types are granites and gneisse.

The present surficial geological structures are a direct result of Pleistocene activities. The glacial forces have gouged and polished the bedrock, depositing erratics and glacio-fluvial materials along their path. In this area continental ice movement tended to run in a south westerly direction while

drift deposits are typically located on the south west sides of ridges and hills (Reference 16). Lacustrine deposits laid down by glacial Lake Agassiz modified the landscape, eliminating many geologic features and reducing the general relief. Only on the most prominent topographic highs is the bedrock easily identified. Stratified silts and clays make up the bulk of the overburden but isolated sand and drift deposits are not infrequent.

The entire reservoir area lies within the area of discontinuous permafrost. Features such as collapse scars, identified by their symmetrical shape and flooded forest are reliable indicators of thawing permafrosted ground in the area. Permafrosted soils vary in thickness and extent, but are less prevalent along the river banks than on the uplands. In thick overburden areas, permafrost is common in the mineral soil and raised clay landforms. The ice content of the permafrost varies from moderate in the mineral materials to high in peat deposits (Reference 5). The vegetation on such sites is quite diversified; spruce (white and black), poplar (white and black), birch, and jackpine grow to a large size on perennially frozen substrate.

Dominant tree associations are a function of materials, drainage and past disturbances. Since much of the north has been burnt over the area exhibits a variety of forest communities. Pure jackpine, trembling aspen and white birch stands are the chief colonizers of burnt over areas, colonizing well drained mineral soil where possibly only spruce grew before the disturbance. The majority of the area is typified by black spruce forest. A specific association of ground and understory flora will be found in each forest community.

The present Rat River is a dynamic system constantly eroding, transporting and depositing materials along the entire route. As a consequence, fluvial land forms are continuously being created and modified. Materials eroded in the upstream reach will determine in part the ultimate shape of downstream shorelines. Along uniform stretches of the river channel where the stream turbulence is greater than the settling velocities, eroded sediments are carried downstream. Carrying velocities are decreased within the river bays and lake inlets resulting in the deposition of transported sediments. This material is sorted since different velocities cause settlement of various particle sizes. As a consequence silt bars are formed along the channels and river bays, creating frequent marshes (Photographs 80 & 81). These depositional areas are a suitable substrate for an assortment of marsh species: sedges, bulrushes, horsetails and submerged aquatics.

In its upper reaches the Rat River is of a meandering nature. The immediate banks are low and probably overtopped by heavy spring run-off. Behind these banks is a marshy area which rises slowly until the level of the general topography is reached. The valley deepens and the banks rise somewhat downstream; the river becomes sinuous as it meets the first rapids a few miles above Karsakuwigimak Lake. Marshes are frequent along the shorelines. The lakes along the Rat show characteristic bedrock promontories and alluvial embayments. Beaches are not extensive but are frequent. Between Karsakuwigimak and Rat Lakes, the irregular channel boundaries are much the same as those found on the aforementioned lakeshores. Below Rat Lake, the relief increases, the river flows between rock ridges with little overburden and rapids are more frequent.

EVIDENCE OF HIGHER HISTORIC WATER LEVELS:
A more detailed description of the Rat River, adjoining lakes and tributaries as divided into reaches and as shown in Figure 78, follows after the discussion on the post glacial lake levels of the Rat River.

Along the diversion route there is quite strong evidence to indicate that water levels in the Upper Rat River System from Notigi Lake to South Bay on South Indian Lake were at one time much higher than at present. This former high water level is marked by a strandline which was identified at numerous points in the backshore area of the various lakes and channels of the Upper Rat (Photograph 82). Profiles measured on Rat Lake and Notigi Lake showed consistently that the strandline was at elevation approximately 837 feet on Notigi Lake. This would indicate that at one time in the history of the area, a large lake existed extending from the rapids just south of Notigi Lake on the Rat River to the low divide separating Issett Lake from South Bay on Southern Indian Lake. This former lake will be referred to as Old Lake Notigi.

The configuration of the old strandline varies depending on the materials on which it was formed and on the extent to which it was exposed to wave action. The variation is the same as that shown by shorelines on present lakes in the area. A common profile on what were exposed shorelines on Old Lake Notigi is a bare or thinly covered bedrock and/or boulders rising to the base of a low clay bank (Figure 79). The contact between the bedrock and the clay bank represents the maximum water level on the old lake. There is often a marked contrast in vegetation between the rocky zone below the strandline and the clay bank. The trees on the clay bank are much healthier. Quite commonly the strandline is marked by a good growth of aspen on the clay bank which is better drained than the terrain farther back.

In the shallow indentations along the old strandline it is common to find thin sand deposits indicating a former beach. This thin sand deposit often extends down to the present shoreline where a sand beach may be present. In large deep indentations or former bays there is little evidence of a former strandline. The terrain rises gently with no significant break in slope. This is quite compatible with the situation in many existing bays where willow and alder swamps are common. Much of the terrain in these former bays is affected by poor drainage.

Aerial photographs give the best appreciation of the old strandline. The break in slope formed by the clay bank shows up well on the photographs and is accentuated by the contrast in vigour and type of vegetation. Photograph 82 typifies the old strandline on an exposed site with bare rock below the strandline and the clay bank above.

Little is known of the history of Old Lake Notigi. The extensive thinly covered and bare bedrock between the present shoreline and the old strandline would indicate a gradual lowering in the water level. The duration of each successively lower level was sufficient to remove most of the overburden on exposed sites and to deposit sand beaches in embayments. It is suspected that the lowering of the old lake took place by erosion of a plug in the narrow channel marks the southern

limit of the old lake. It is suspected that Old Lake Notigi and Southern Indian Lake were interconnected at one time. The divide between the Rat River System and South Bay on Southern Indian Lake is less than 845 feet. Also the high water level on Southern Indian Lake is 841 feet.

The old strandline is quite significant in assessing the probable impact of the Notigi Reservoir. The proposed water level in The Notigi Reservoir of 847 feet is only about ten feet above the old strandline. The new waterline will often fall within the clay bank above the old strandline. In fact, for many miles, the old strandline and the new strandline are within 50 to 100 feet of each other horizontally. This is particularly evident on the aerial photographs. Several lessons can be learned from the old strandline in assessing the new strandline.

PHOTOGRAPH 80 - Silt bars along the Rat River channel. Silt bars have built up along the inside of channel sections. Allogenic soil processes precede the autogenic plant successional processes. However, plant succession will only develop to a certain extent due to annual spring flooding.

a) The most severe erosion will take place along exposed sites.
b) The ultimate configuration of the new reservoir shoreline will be much the same as that of the old strandline - the headland controls are well established.
c) On exposed sites there will be extensive bare rock in the offshore zone.
d) Sandy bottom conditions will be present in the zones offshore of former embayments.

PHOTOGRAPH 81 - Depositional sites in embayments along the Rat River. Marsh zones are wider in embayments along the Rat River where velocities are reduced resulting in the settling of water suspended materials. This riparian zone is a suitable food source for a number of faunal species.

PHOTOGRAPH 82 - Strandline of Old Lake Notigi, at Notigi Lake. Since the decline of Old Lake Notigi levels, the rock beach is devoid of woody vegetation. The clay bank above the rock beach is usually populated with willows and poplars while a variety of annuals become established on the rock pavement.

NOTIGI RESERVOIR - MAPPING DIVISIONS

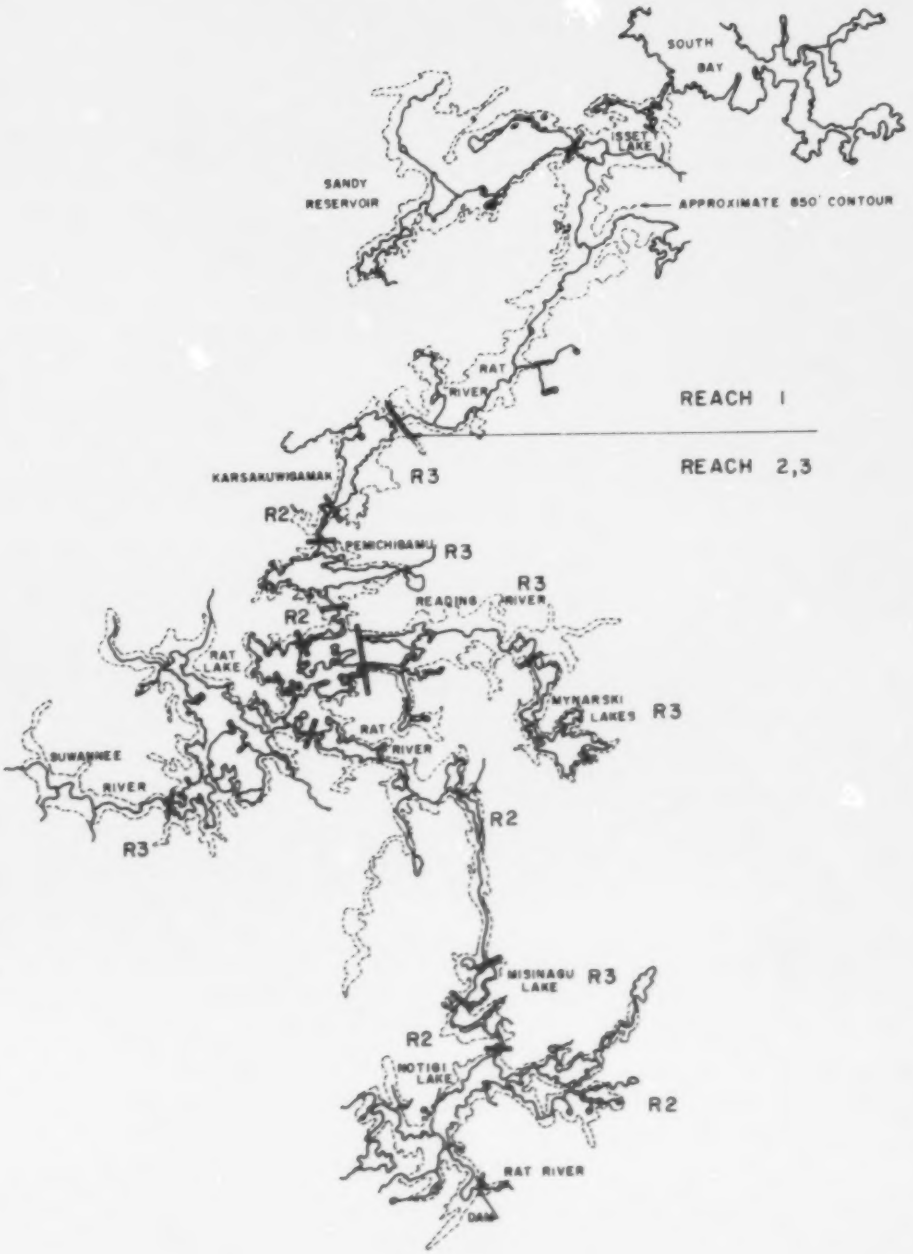


FIGURE 78

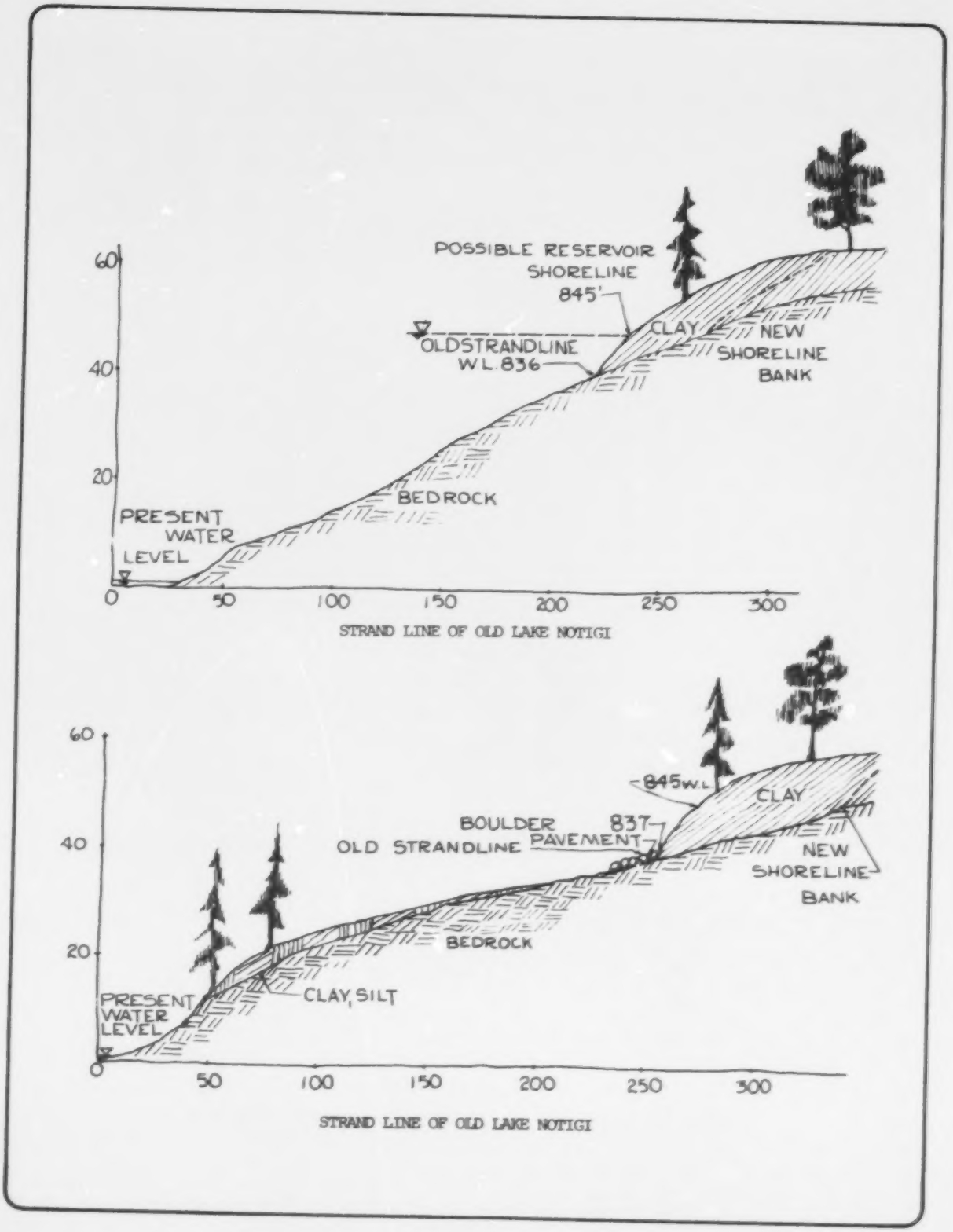

60
40
20
0
50
100
150
200
250
300
POSSIBLE RESERVOIR SHORELINE 845'
OLDSTRANDLINE W.L. 836
CLAY
NEW SHORELINE BANK
BEDROCK
PRESENT WATER LEVEL
STRAND LINE OF OLD LAKE NOTIGI
60
40
20
0
50
100
150
200
250
300
845 W.L.
CLAY
BOULDER PAVEMENT
837
OLD STRANDLINE
NEW SHORELINE BANK
BEDROCK
CLAY, SILT
PRESENT WATER LEVEL
STRAND LINE OF OLD LAKE NOTIGI

FIGURE 79

NATURAL STATE OF EXISTING SHORELINES: In order to more accurately describe the Rat River, the shorelines have been divided into several reaches that differ in certain major characteristics. The mapped area and shoreline distances are shown in Tables 7, 8 and 9 and in Figures 80, 81, 82, and 83.

Reach 1R - Reach 1R includes the entire channel joining Issett Lake to Karsakuwigimak Lake and the chain of lakes due west of Issett. The general relief of the terrain is low and drainage is characteristically poor. The river winds within a much larger valley which is approximately one mile wide. The river is about 100 feet wide; it is narrower near Issett Lake and wider at the lower end of the reach. With minor exceptions the channel banks are generally low alluvial with extensive areas of marsh on either side. The exceptions occur within the two rapid sections having bedrock shorelines. Above these rapids, the channel meanders, while below the rapids the river pattern can be described as sinuous.

Issett Lake, the head water of the Rat River drainage is 475 acres in size. The low relief of the terrain and lacustrine clay overburden are the prime reasons for establishment of the 4.2 miles of Low Willow (Type 28) and 2.7 miles of Clay Shoreline of Moderate Height (Type 23) shoreline on Issett Lake. Stream inlets on the lake, particularly in the northeast and western areas, are sites of deposition. With the settling of the suspended silt load, marsh zones have become established.

The chain of lakes west of Issett Lake (approximately 4,000 acres) are shallow in nature. Predominent shorelines are Type 31 and 28. The headwater of the chain, Grass Lake which is four to six feet deep, is thickly colonized by floating aquatics. This lake was probably named after the abundant floating grass-like vegetation that permeates its waters. Grass Lake drains into Pear Lake which is approximately six to eight feet deep and not as thickly colonized by aquatics. Pear Lake drains eastward through a rapidly flowing stream into Issett Lake. Meadow Lake characterized by the extensive sedge meadow shorelines is the northernmost and smallest of the lakes. Sedge meadows surround the majority of the lake. Meadow Lake drains into the stream running from Grass and Pear Lakes. All stream areas are densely populated with a variety of aquatic flora.

At the outlet of Issett Lake, the Rat River forms a meandering channel, straightening out as it approaches Karsakuwigamak Lake. From Issett, the channel is narrow but widens considerably at the junction of Missipakiow River better known as "The Big Turn Off".

Three shoreline types fully define the rivershore (Types 13, 23 and 28). Most common is Type 28m, Low Willow Shoreline, which comprises about 35 miles of shoreline (Photograph 83). The majority of the Low Willow Shoreline occurs on a silty clay levee system. Backshore areas of the levees consist of Sedge Communities and Treed Muskeg Areas.

The Type 28 shoreline profile is low and virtually horizontal. Surficial materials of silty-clay are underlain by bedrock. There is little exposed bedrock in the flood plains. The river bed and banks are also of silt and clay. Offshore vegetation most commonly consists of Gramineae and Carex spp., with

frequent stands of Scirpus sp. The marsh area varies in width up to several hundreds of feet. Back from the water's edge for some distance is a zone of poor drainage and of closed deciduous shrub. Salix sp., being dominant along with Alnus sp. and scattered Picea mariana. Ground cover may range from Gramineae to feather mosses of Sphagnum spp.. This zone grades into the upland vegetation of dense Picea mariana, Populus tremuloides, Picea glauca, etc.

The second most common shoreline is Low Bedrock (Type 13). Four miles of Bedrock Control Shoreline are broken up into small stretches along the system. It is in these areas that sets of small rapids are located (Photograph 84). Most of the seven foot drop in mean elevation from Issett to Karsakuwigimak occurs along this shoreline type.

Type 13 is characterized by the overburden being perhaps thinner than normal and the water-washed zone is virtually free of vegetation except for lichens on boulders. Vegetation behind the outcrop is a closed coniferous forest containing Picea mariana and glauca and frequent Populus tremuloides and Betula papyrifera. Some Alnus provides the understory. A ground cover of Ledum groenlandicum, Arctostaphylous uva-ursi, Aralia nudicaulis, Cornus canadensis, Pteridium sp., Linnaea borealis, feather mosses and Sphagnum sp., is common. The remaining three miles of Shoreline are Clay Shorelines of Moderate Height and Mild Slope (Type 23). For the most part, this classification shows up at the head of Karsakuwigimak Lake. The material, mostly silt-clay, but occasionally sand, is either of lacustrine of fluvial origin. Initially the shoreline rises 10 to 15 feet and then more slowly slopes to about 30 to 35 feet above the river. Bedrock is three feet or farther below the surface. Permafrost occurs frequently in this overburden. Marsh vegetation consists of Potomageton spp., Equisetum sp., and Scirpus sp. On shore is found the previous vegetation plus Populus balsamifera and Salix sp. The next zone is a closed deciduous forest including Populus balsamifera (dominant) and Betula papyrifera. This grades into a closed coniferous forest, the predominant species being Picea mariana with some Larix laricina. The understory of Salix spp., and Alnus sp., is less dense than in the previous zone. Ground cover throughout includes Ribes spp., Rosa spp., Lycopodium spp., and Sphagnum spp.

PHOTOGRAPH 83 - Type 28 shoreline, Rat River. Shallow zones in channel expansions are typically colonized with horsetail, sedges and willows. Collapsing of permafrosted Treed Muskeg is evident along the forest edges in the background.

PHOTOGRAPH 84 - Type 13 Shoreline, Rat River. In f equent stretches of bedrock are the sites of rapids where water fowl were often observed.

Reach 2R - Reach 2 covers the remaining length of the channel on the Rat River but excludes the lakeshores in the region. The relief of the landscape increased from Karsakuwigimak through the Rat Lakes and remains fairly constant through to Notigi Lake. The river in this stretch is bedrock controlled in the vertical and frequently in the horizontal. As a result, the channel shape is very irregular. The overburden is deep enough to mask details of the underlying bedrock topography. In the first few miles, a combination of Types 13 and 23 constitute the shoreline. As relief increases, Type 23 gives way to Type 14, although it is still evident at the inlets and outlets of the lower lakes. Small marshes of Type 28m are found in embayments and where small tributaries join the main stream.

The shorelines classified as 13 in this reach are not unlike those in the previous section. The water-washed zone is about 10-15 feet, and is devoid of vegetation. Closed coniferous forest is prevalent behind the exposed bedrock. The dominant species may be either Picea mariana or Picea glauca, but Populus tremuloides, Populus balsamifera and Betula papyrifera are also common. Similar understory and herb communities as described in the previous section exist here on a ground cover of feather mosses and Sphagnum spp. About 45 miles of shoreline may be represented by this profile.

The stretches of bedrock not accounted for by number 13 are classified as number 11. These slopes are much steeper and in this case much higher. There is less than one mile of shoreline with this characteristic between Misinagu and Notigi Lake. Vegetation is completely different from that portrayed on the drawn profile. This area has been burned over. There is a regrowth of the following species: Populus tremuloides, Alnus sp., Betula papyrifera, with some Pinus banksiana and Picea mariana. Ground cover consists of some Gramineae and lichens with Fragaria virginiana, Epilobium angustifolium, Rosa spp. and Ribes spp.

Classification 14 shoreline is very common and is about 24 miles in extent. It is generally found in association with Type 13. A lacustrine clay with silts and sands overlies the bedrock which does not outcrop except on the backshore. The initial slope is shallow but steepens farther back. This is dependent on the bedrock contours. Carex spp., and Salix sp. dominate the shoreline in a zone about 30 feet wide extending some 20 feet into the water. Immediately behind the shoreline zone, begins a predominantly closed coniferous forest with occasional deciduous zones. Picea glauca is predominant. Picea mariana exists in heavy concentrations near the shoreline but thins as the slope increases two hundred feet back.

Occasional Pinus banksiana exist on the slope. The deciduous component is made up mainly of Populus tremuloides with some Betula papyrifera. Average heights of these trees are 50-60 feet. A generally dense understory consists of Alnus sp., Cornus stolinifera and Juniperus communis. Groundcover and herbs include Aralia nudicaulis, Oxycoccus microcorpus, Ledum groenlandicum Campanula sp., Cornus canadensis, feather mosses and Sphagnum spp.

There are about 18 miles of Type 23 shoreline in this reach. It is the same in Reach 2 as was described in Reach 1.

A few small marshes exist in embayments along the river. They are classified as Type 28m. and total about eight miles in length. These shorelines are narrower than in the previous reach and the backshore rises more steeply, but vegetation and stratigraphy remain very similar.

Reach 3R: Reach 3R encompasses the lake areas and major inflowing river systems along the Rat River. The lakes included in this discussion are Karsakuwigimak, Pemichigamau, Rat, Mynarski, Misinagu and Notigi while the river areas consist of the Reading and Suwannee Rivers.

The lake and river areas within this reach exhibit a greater variety of shoreline types than the previous two reaches. The most common shoreline material is bedrock and most frequently it is of low relief. Bedrock and Bedrock Controlled Shorelines become increasing predominant in the lake areas. Type 13A shorelines constitute about 57% of the total shoreline distance in Reach 3 as opposed to 48% in Reach 2 and 8% in Reach 1.

Reach 3 has a total of 207 miles of Type 13A shoreline.

Joining the stretches of bedrock are Bedrock Controlled Shorelines with alluvial land-water interfaces. These are 35 miles of Type 14 and 16 miles of Type 15 shoreline.

The water washed zone of the bedrock shorelines have stretches of sand beach about 25 feet wide. Sparse Carex spp. and Gramineae are found here. Closed coniferous forest dominates behind the outcrop. The main species are Picea glauca, Picea mariana, and Pinus banksiana. There are some Populus tremuoides and scattered Populus balsamifera. Alnus sp. dominates the understory in conjunction with Viburnum trilobum, Ledum groelandicum, Arctostaphylos uva-ursi.

The greater relief in this reach lends itself to the existence of a limited extent of Steep Bedrock Shoreline (Type 11). The four miles of Type 11 shoreline vary from the typical profile in that the backshore areas are characterized by a lacustrine clay overburden above old Lake Notigi strandline. The bedrock rises about 30 feet out of the water in a horizontal distance of about 50 feet. In this first zone Gramineae and lichens comprise the vegetation. Still on the rock but behind this zone, sparse Picea mariana, Picea glauca and Pinus banksiana exist. The profile then drops down to a closed coniferous forest of Picea mariana, Picea glauca with some Populus balsamifera and Betula papyrifera. Salix sp. and occasional Alnus sp., and Ribes sp. constitute the understory. The typical herbs such as Cornus canadensis, Arctoslaphylos uva-ursi, etc. grow on a thick layer of feather mosses and Sphagnum spp.

Clay Shorelines of Moderate Height and Moderate Slope (Type 23) form continuous stretches of shoreline along river areas while they are only contained within embayments on the lakes. Twenty-two miles of this shoreline exist in Reach 3. The only apparent difference between this and other occurrences is that the zone of Populus balsamifera and Salix sp., extends farther from the water's edge into embayments. There is more likelihood of a beach-like pattern developing.

Found along river channels and lake embayments, often in conjunction with Type 14 and 23 shorelines, are the Low Willow (Type 28) shorelines. They are not as extensive as those in Reach 1. Reach 3R consists of some 41 miles of such shoreline.

The 22 miles of Low Alluvial Shorelines (Type 24) are confined to the river areas within this reach.

The remaining shorelines, Treed Muskeg (Type 26) and Fen (Type 31) make up 6 and 14 miles of shorelines respectively. Both types are localized in extent.

Types 24 and 26 shorelines exhibit characteristics typical of the drawn profile while Type 31 is not as extensive as that shown in section 5.2.1.

The characteristic features and predominant shoreline types will be briefly discussed for each lake and river area within the Reach 3R.

Karsakuwigamak Lake: Karsakuwigamak, 4,249 acres in size, is typical of most lakes found within the Canadian Shield. The shorelines are predominantely bedrock controlled with little or no exposed outcrops in the backshore area. Geologically, each side of the lake is characterized by its own lithology which was a factor in determining the overall shape of the lake.

Low Bedrock is the most prevalent type forming continuous stretches of shoreline broken by Types 11, 14, 23 and 28. Type 28 is predominant along the east shore in stream mouths while Type 23 constitutes a significant portion of the west shore. Offshore areas of both shoreline types are characterized by submerged and emergent aquatic vegetation. The inlet at the north end of the lake is extremely shallow and consequently overgrown with submerged vegetation. Materials settling from the Rat River are responsible for the alluvium built up in the lake.

Types 11, 13, 14, 23 and 28 consist of 1.2, 9.9, 1.3, 3.5 and 4.9 miles of shoreline respectively.

Pemichigamau Lake: Pemichigamau is 5,141 acres in size. Bedrock shorelines are prevalent on Pemichigamau. Exposed shorelines are Type 13A, while Type 14 is confined to the protected and depositional stretches. These two shoreline types consist of 16.4 and 9.6 miles of shoreline respectively. Unlike Karsakuwigamak, sand beaches are frequent along the Bedrock Controlled Shorelines.

The three miles of Type 23 and one mile of Type 28 are confined to the larger embayments within the lake area extremities. Typically, these shallow areas are densely populated with a variety of marsh vegetation.

Rat Lake: Rat Lake, 18,353 acres in size, is by far the largest single body

of water along the Rat River system. An irregular body of water, consisting of a complex pattern of linear bays and promontories, and numerous islands, the overall lake configuration reflects the underlying bedrock lithology and structure. Prominant ridges and exposed bedrock distinguish it from most other lakes along the river system. In places, the relief is such that the ridges are 150 to 200 feet above the low lying valleys. Approximately 40% of the bedrock in the area is exposed.

The shoreline is almost all bedrock controlled. The majority of the 116 miles of Type 13A shoreline are characterized by a moderate backshore slope with exposed bedrock in the backshore area. Old Lake Notigi strandline is particularily evident along these backshore areas.

The remaining bedrock shorelines, Type 11 and 14 are spread throughout the lake. Type 11 is limited in extent while the eight miles of Type 14 exhibit granular beaches.

Type 23 shorelines are limited in extent due to the local topographic features. The three miles of Type 23 shoreline present are confined to the north-eastern sector of the lake where overburden materials are available.

Type 31 shorelines are contained along stream outlets while Type 28 shorelines occupy the embayments. In both cases well developed marshes exist in the offshore areas. Types 31 and 28 represent 8 and 12 miles of shoreline respectively.

Suwannee River: The Suwannee River runs through an area of low relief and deep fluvial and/or lacustrine clays. Thick clay ridges, 40 to 50 feet deep are characteristic of the area (Reference 17).

Upstream, the discernable river banks are Type 23 while Type 31 becomes predominant in the lake area. Type 28 is located at the mouth and along the northern portion of the channel widening. Type 23, 31 and 28 form 11.9, [illegible] and 1.6 miles of rivershore respectively.

Reading River Area: The Reading River Area consists of a channel and lake system draining Mynarski Lakes into Rat Lake. The lakeshores are similar to Rat Lake, consisting of Type 13 (27 miles), Type 14 (1 mile) and Type 28 (7 miles).

The channel sector winds through an area of low relief and thick overburden; subsequently, the shoreline is Type 24. In total, this represents 20 miles of river shore.

Mynarski Lakes: The two lakes of concern consist of a total of 4,641 acres. In general, the topography of the area is rugged, characterized by hills and ridges separated by marshes and muskeg. Maximum relief above the low areas is from 250 to 300 feet. These lows are underlain by clay; sand and gravel (Reference 18). Backshore areas, particularly the southern sectors, consist of exposed outcrops.

The Mynarski Lakes shoreline differs from the Rat Lake shoreline by the occurrence of Type 15 and 26 shorelines, each represented by 16 and 5.4 miles respectively. These Low Muskeg Shorelines are confined primarily to the larger low lying embayments.

Types 13A (12 miles) and Type 14(7.4 miles) make up the remainder of the

bedrock control shorelines.

Type 24 is located along channels and in deltas while Type 28 is confined to embayments. Each type is represented by 33 and 1.9 miles of shoreline respectively.

Misinagu Lake: Misinagu Lake, 831 acres in size, is simply a widening in the river channel. The 8.7 miles of Type 13A shoreline exhibits moderate to steep backshore areas. Other shoreline types, 14 and 28 are limited in extent, occurring only along the north eastern portion.

Notigi Lake: Notigi can be divided into two sections: a central and eastern portion. The central portion consists of stretches of alternating Type 13A and 14 shoreline with a large Type 28 embayment in the south-western sector. The northwest stretch of shoreline is readily distinguishable from the remainder of the lake by the 2.2 miles of steep bedrock lakeshore.

Type 28 shorelines become increasingly predominant in the eastern portion of the lake. It is in this area that the half mile of Type 23 shoreline is situated.

In total Type 13, 14 and 28 make up 15.9, 6.6 and 11.7 miles of shoreline respectively.

Inundated Terrain: Areas considered as Inundated Terrain are those which lie beyond the natural shoreline backshore areas as defined in Section 5.2.3. The Inundated Terrain types for each reach are as shown in Figures 80 to 83 and are listed in Table 8. The following discussion will deal with the physical character of the land that falls within the inundated area not already covered under Existing Shorelines of this section. This encompasses the larger portions of the Rat River drainage system.

Each reach will be discussed separately.

Reach 1R: The Inundated terrain of Reach 1 includes the area from South Bay to Karsakuwigamak and the chain of lakes due west of Issett.

The entire area is characterized by extensive thick organic, lacustrine clay, silt and drift deposits. Overall relief is low with infrequent bedrock outcrops. Sedge Communities and Treed Muskeg occupy the areas of low relief while the lacustrine clay areas are of a gently undulating nature. Permafrost exists to a large extent in Clay Overburden and well drained Treed Muskeg Areas.

The inundated area west of Issett lake contains 7,412 acres of Sedge Communities, 14,574 acres of forested bedrock, clay and drift substrate and 4,129 acres of natural water surface area.

The majority of the forested area consists of stunted Treed Muskeg interspersed with collapse scars. The best tree stands in the area are confined to the higher Drift Deposits. The acreage of the drift area was not measured separately due to the sporadic distribution of the materials.

The Sedge Communities consist of a variety of large fens and bogs. Fens are located in areas adjacent to lakes and streams while bogs are confined to backshore areas. Many of the bogs in

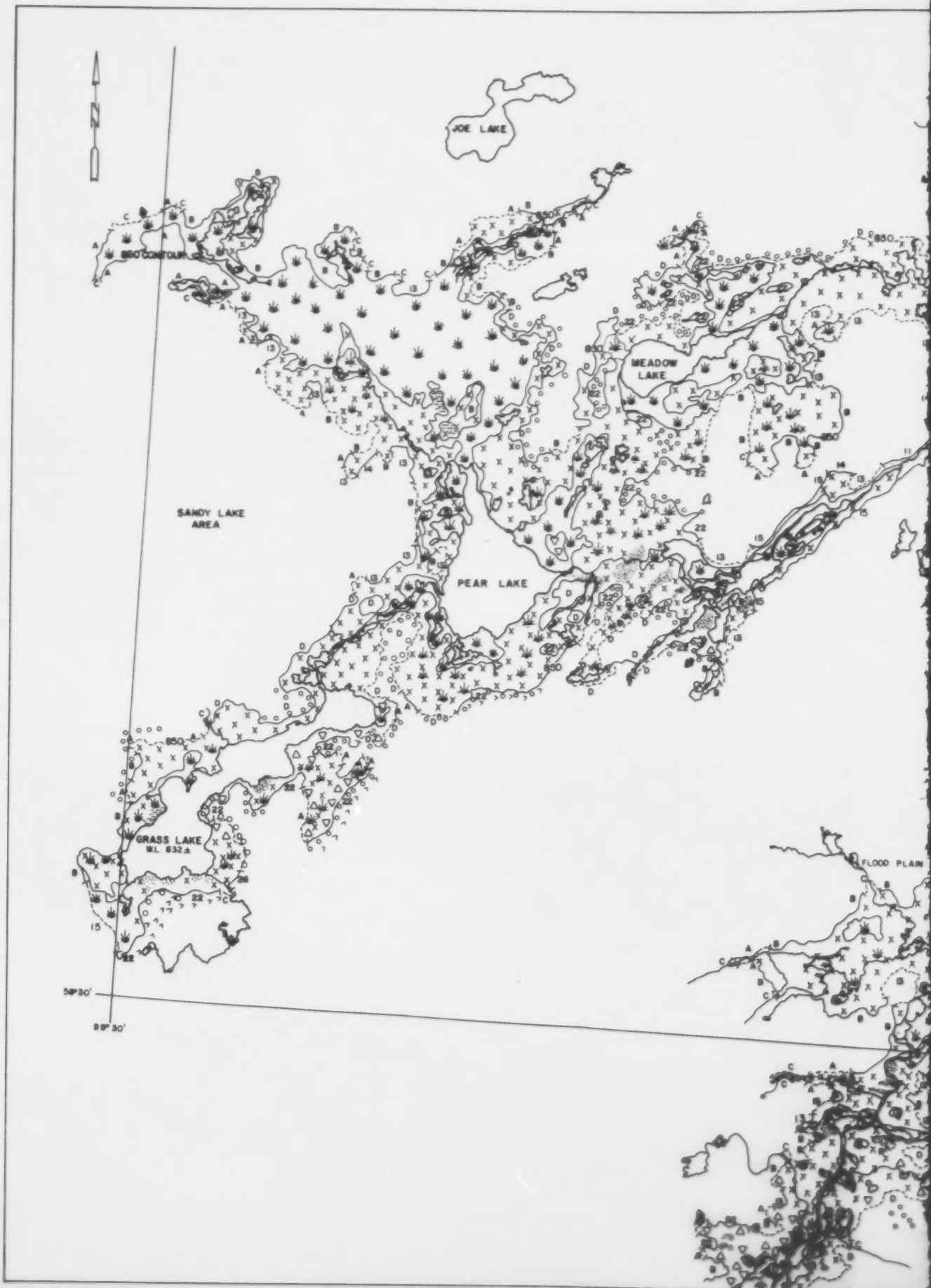
the area are colonized by tamarack and black spruce. An example of the peat accumulative process occurring in the area is the large bog south of Joe Lake (Photograph 85). This site was at one time a large shallow lake. Barring any edaphic change, the site would develop into Treed Muskeg.

The area between South Bay and Karsak-uwigamak is part of a large valley floodplain averaging a mile in width. Present day Rat River is simply occupying an abandoned lake bottom or river channel. The phenomenon and significance of Old Lake Notigi has already been discussed in this section.

In the river valley 3,834 acres of Sedge Community, 28,068 acres of forested land and 2,662 acres of backshore water bodies lie within the inundated area. Adjacent waterways are densely colonized with horsetails and sedges. In most cases, the horsetail growth is so thick that it is hard to manouver a canoe through the stand. Of the forested land, Treed Muskeg occurs in areas of low relief while a variety of coniferous and deciduous growth can be found in the well drained lacustrine clay and drift areas. Permafrosted organic and mineral soil are common place throughout the reach. Fens predominate along waterways draining into the Rat River while bogs are confined to the backshore areas (Photograph 86, Figure 84). The youthfullness of many of the sedge communities suggests that they are the direct result of collapsing permafrost sites. Such collapse scars are readily identifiable throughout the entire floodplain.

Throughout the valley a significant portion of the level backshore area consists of inundated forest. The dominant tree cover on all such sites along the system is white birch, indicating that this backshore area had been a moist, well drained area, prior to flooding (Photograph 87). This particular area was supporting a dense stand of bogbean Menyanthes trifoliata in a foot of water. Similar sites investigated along the Burntwood River had completely grown over with sedge. Although unstable, the floating matt would support a man. On the Burntwood, the higher adjacent areas were permafrosted and slowly collapsing, however, there was no evidence of past or present thawing along the Rat River. All inundated forests remained intact.

Areas backshore of the Rat River levee system could either be recent permafrost collapse sites or else floodplain forests. In either case, flood waters rising over the levees caused the inundation. The levee itself likely obstructed drainage creating a slack water zone. Once flooded the forests are transformed into marshes. Being along a river system localized areas may in fact be flood plain forests. If this is the case, the inundation and following plant successional processes are a cyclic phenomenon (Figure 85). Both these progressive and regressive stages will require decades to complete.


N
JOE LAKE
850 CONTOUR
MEADOW LAKE
SANDY LAKE AREA
PEAR LAKE
GRASS LAKE
W.L. 832±
FLOOD PLAIN
50°30'
99°30'

JOE LAKE

(SOUTHERN INDIAN LAKE)

SOUTH BAY W.L. 939

THIN LAKE

850 CONTOUR

GRASSY LAKE

MEADOW LAKE

ISSETT LAKE W.L. 822±

NDY LAKE AREA

PEAR LAKE

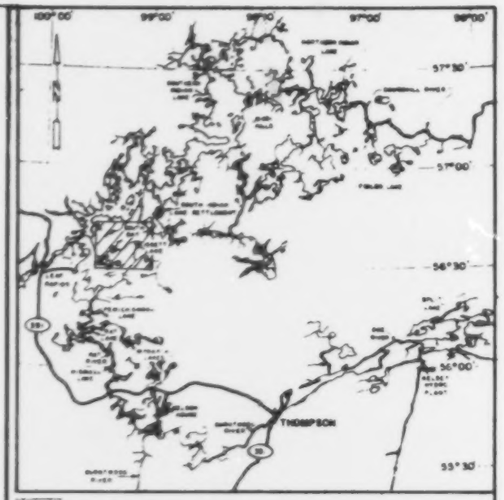
MISSIPAKIOW RIVER

FLOOD PLAIN FOREST

0 1 2 3 4

½ 1½ 2½ 3½ 4½

SCALE IN MILES



LOCATION PLAN

0 20 40 60

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
X_s X_w	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 80

PROVINCE OF MANITOBA
DEPARTMENT OF MINES RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
NOTIGI RESERVOIR
ISSETT LAKE AREA
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DESIGN	CHECKED	RECOMMENDED	APPROVED
T. M.	S. P.	F. P.	DATE	DATE

SCALE	DATE	SHEET NO	FILE NO
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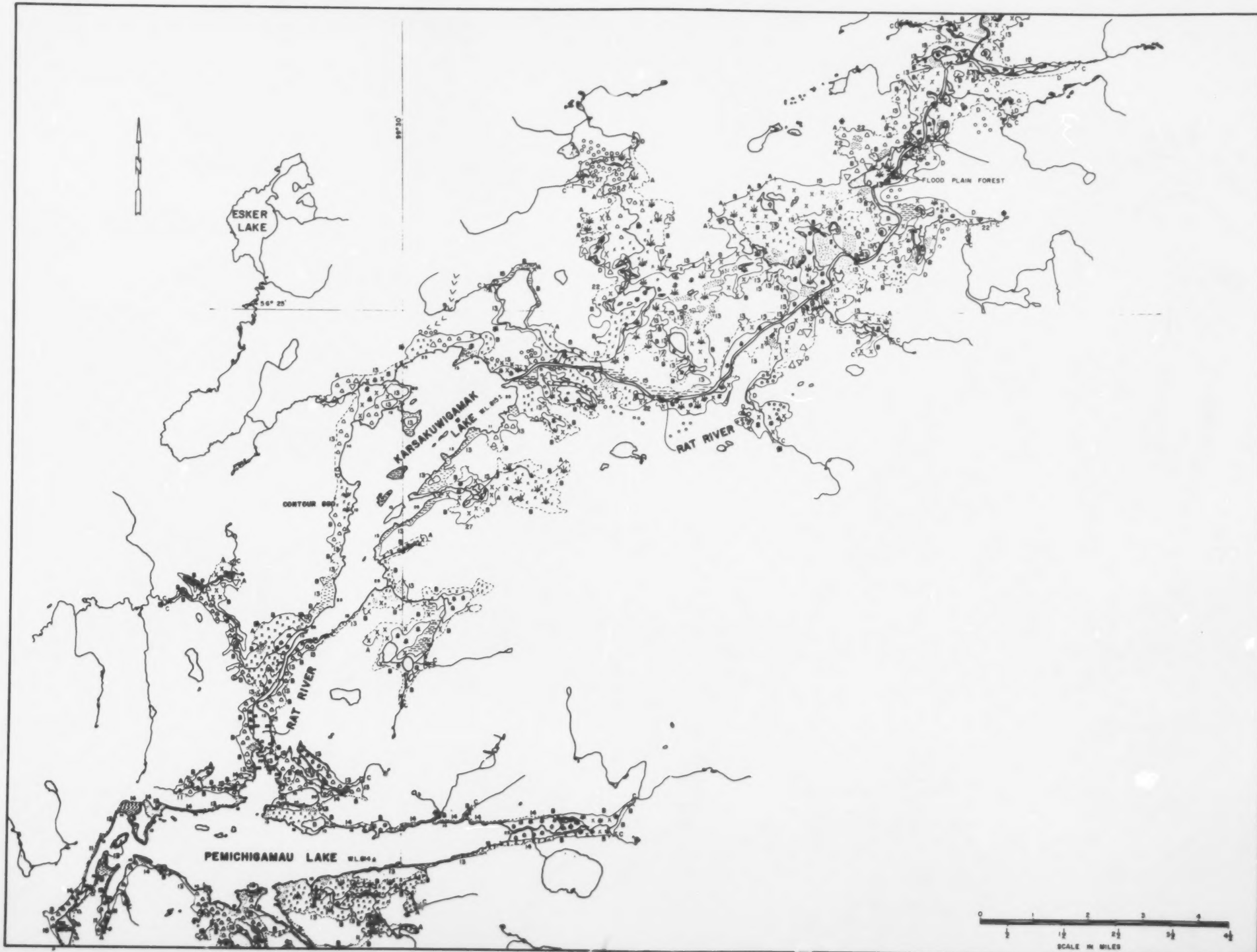
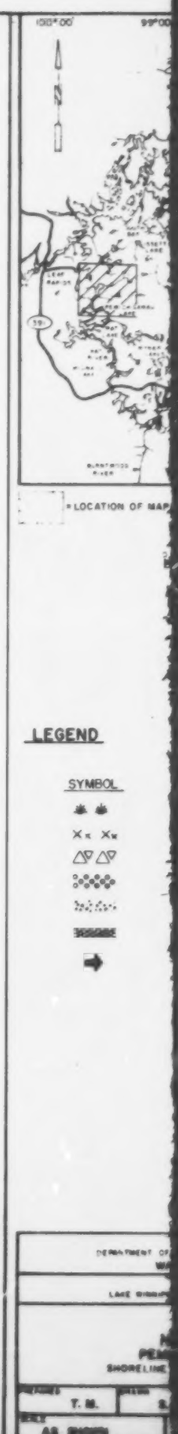
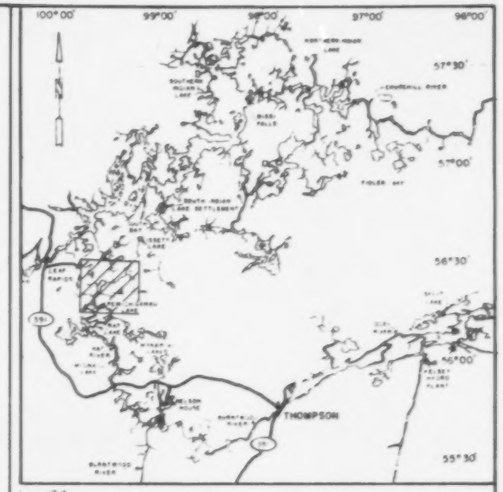

ESKER LAKE
56° 25'
89° 30'
KARSAKUWIGAMAK LAKE
RAT RIVER
FLOOD PLAIN FOREST
CONTOUR 900
RAT RIVER
PEMICHIGAMAU LAKE
0 1 2 3 4
½ 1½ 2½ 3½ 4½
SCALE IN MILES


LOCATION OF MAP
LEGEND
SYMBOL
T. M.
AS SHOWN



LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
X_x X_w	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

0 1 2 3 4
½ 1½ 2½ 3½ 4½
SCALE IN MILES

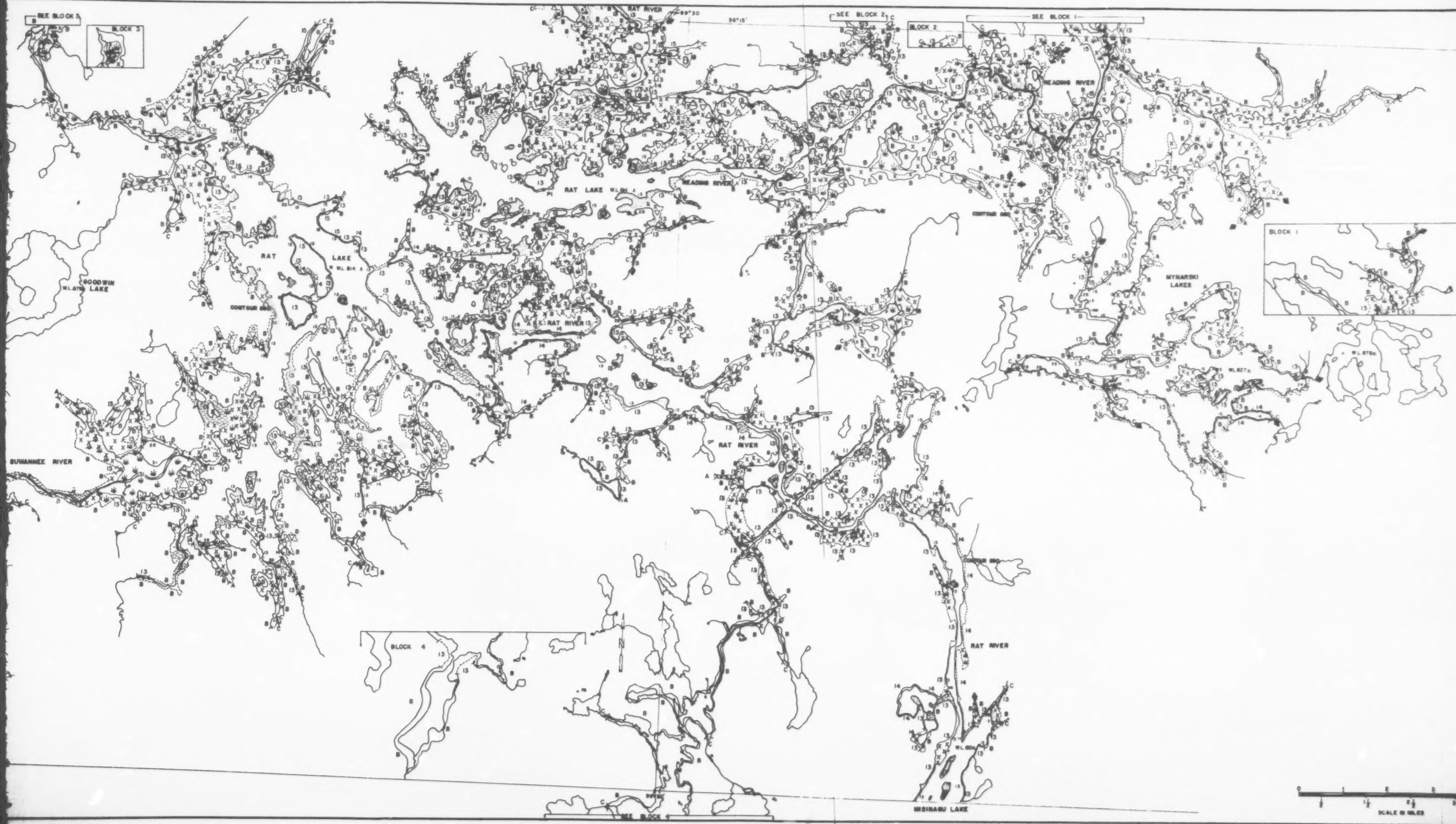
FIG. 81

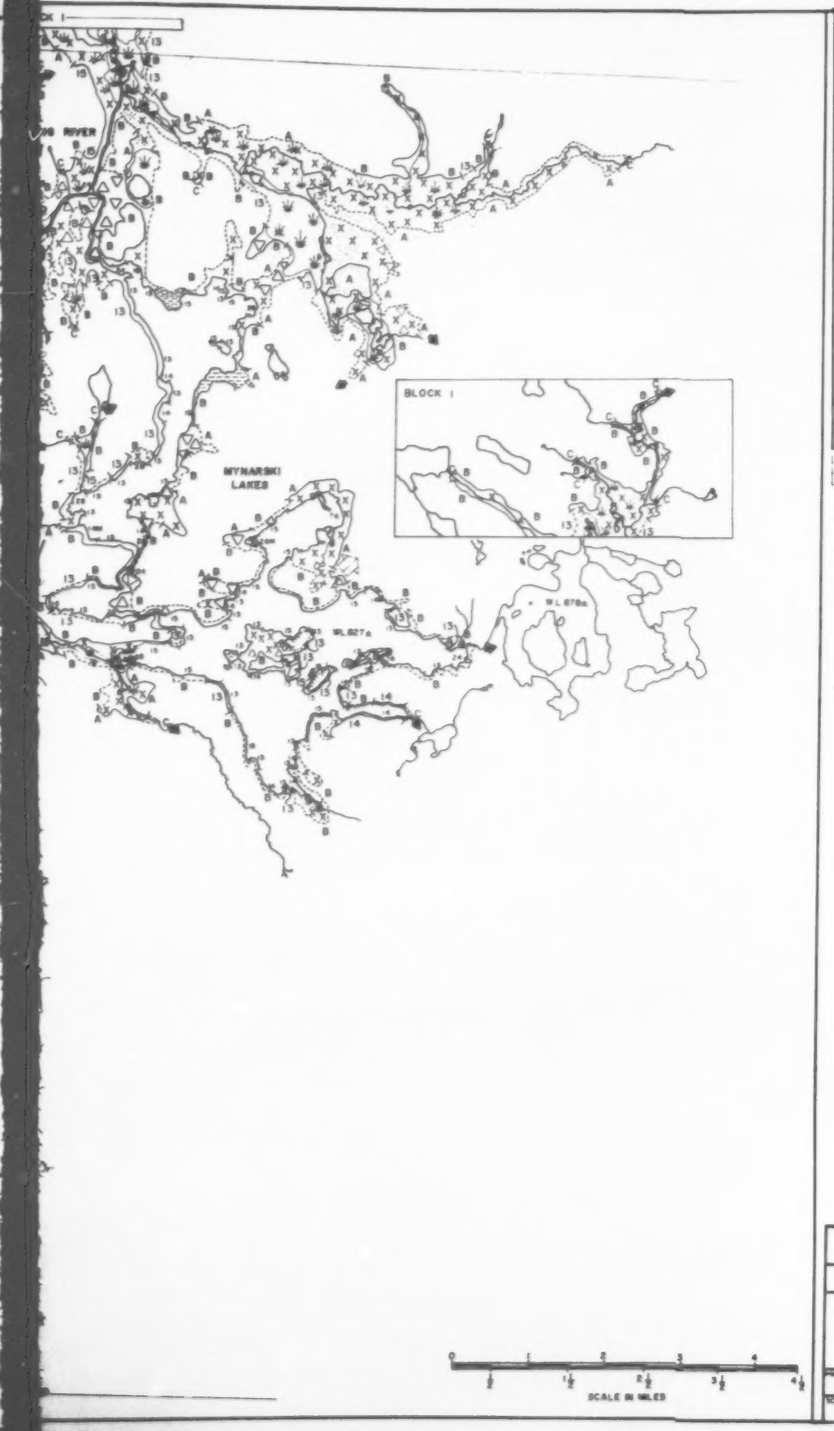
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

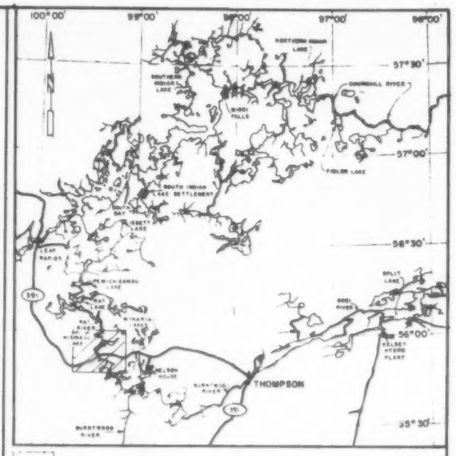
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
NOTIGI RESERVOIR
PEMICHIGAMAU LAKE AREA
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUPERVISOR DATE	APPROVED DATE
T. M.	S. P.	F. P.		
SCALE	DATE	SHEET NO	FILE NO	
AS SHOWN	APRIL / 76	8 OF 88	61-1-1029	


SEE BLOCK 3
BLOCK 3
RAT RIVER
89°30
50°15'
SEE BLOCK 2
BLOCK 2
SEE BLOCK 1
MEADOW RIVER
RAT LAKE W.L. 814 ±
GOODWIN LAKE
W.L. 870±
CONTOUR 880
RAT LAKE
RAT RIVER
MYNARSKI LAKES
BLOCK 1
W.L. 870±
W.L. 827±
SUWANNEE RIVER
RAT RIVER
BLOCK 4
N
SEE BLOCK 4
W.L. 650±
MISINAGU LAKE
SCALE IN MILES





LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	MIXED COMMUNITIES
X_x X_x	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

SCALE IN MILES

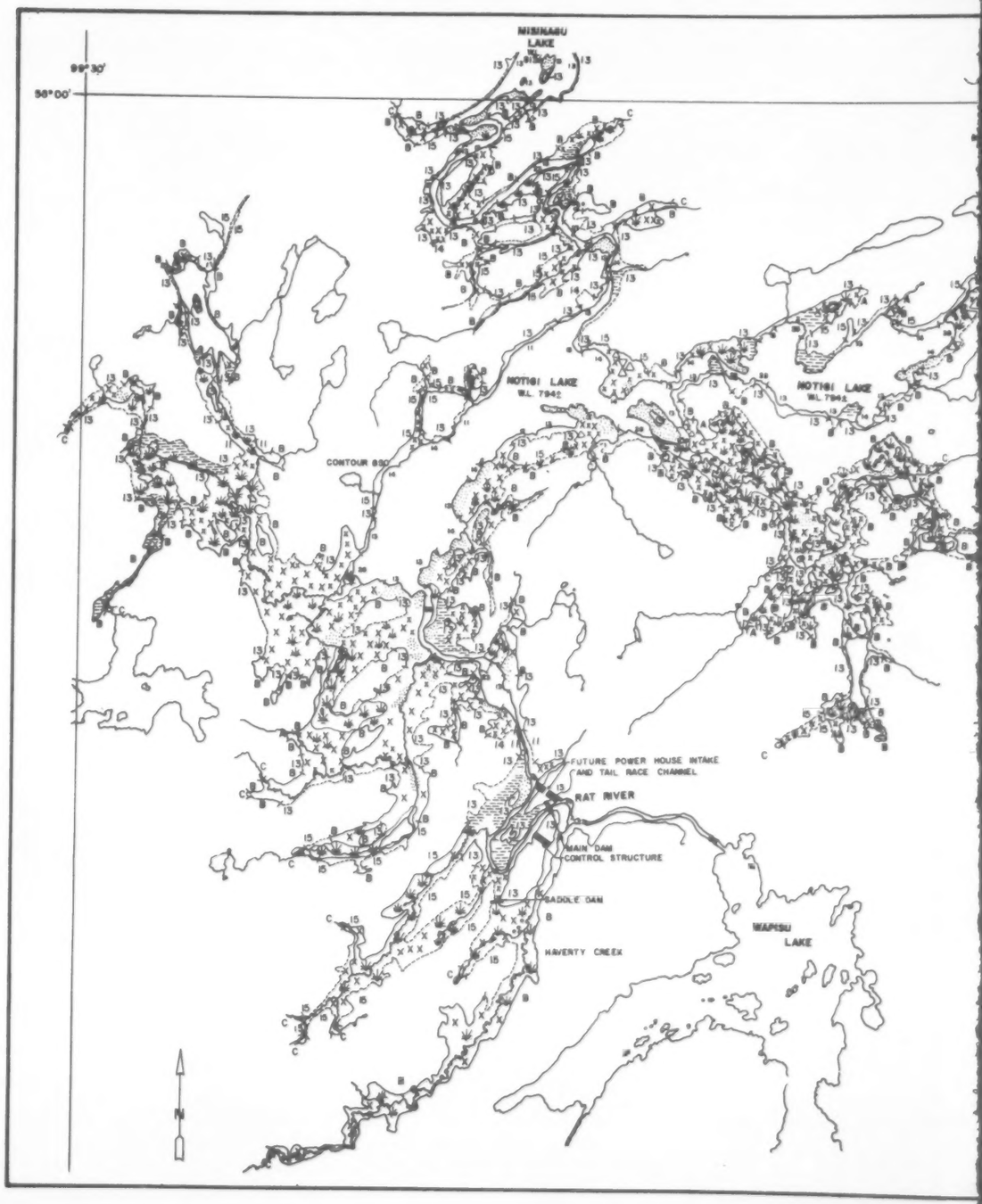
FIG. 82

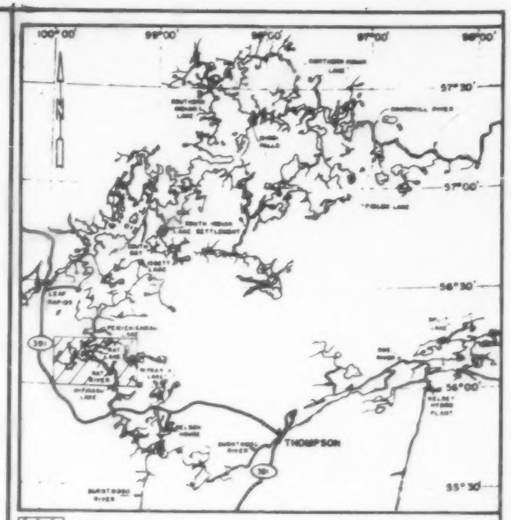
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
NOTIGI RESERVOIR
RAT LAKE AREA
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
T. M.	S. P.	F. P.	DATE	DATE
SCALE: AS SHOWN	DATE: APRIL /76	SHEET NO. 9 OF 89	FILE NO. 61-1-1026	





LOCATION PLAN

0 20 40 60

SCALE IN MILES

0 1 2 3 4

½ 1½ 2½ 3½ 4½

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xm Xm	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

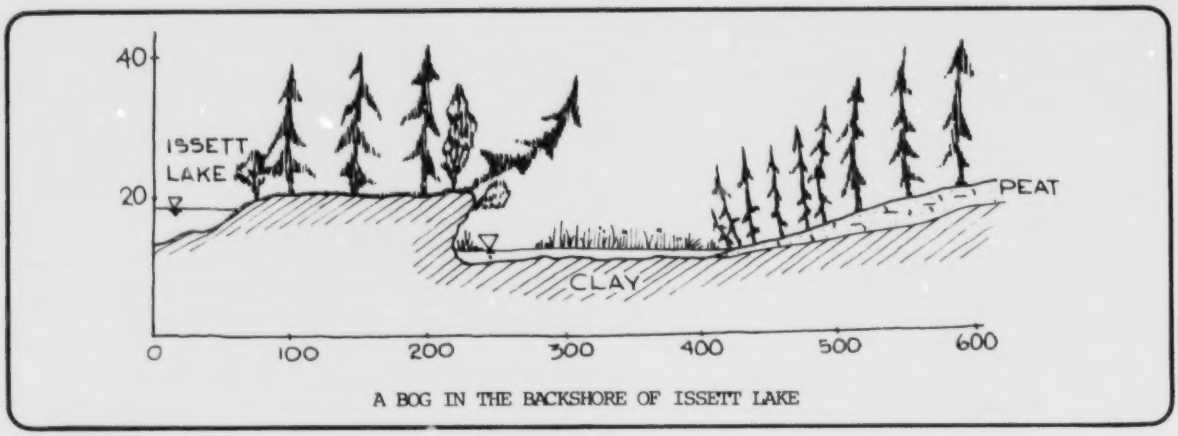
FIG. 83

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
NOTIGI RESERVOIR
NOTIGI LAKE AREA
SHORELINE AND INUNDATED AREA CLASSIFICATION

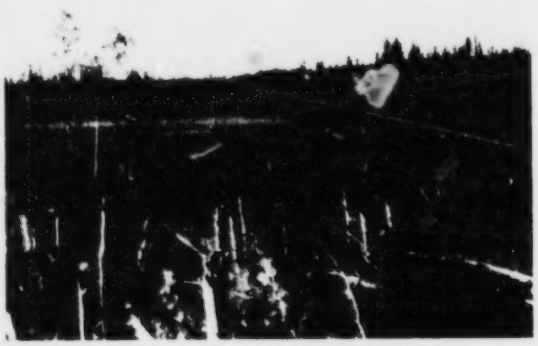
PREPARED	DRAWN	CHECKED	SUBMITTED / DATE	APPROVED / DATE
T. M.	S. P.	F. P.		
SCALE AS SHOWN	DATE APRIL / 74	SHEET NO. 10 OF 38	FILE NO. 61 - 1 - 1025	



A BOG IN THE BACKSHORE OF ISSETT LAKE

FIGURE 84

PHOTOGRAPH 85 - A bog meadow south of Joe Lake. Permafrost collapsing occurs along the periphery. Drift substrate affects tree growth.



PHOTOGRAPH 86 - A bog in the backshore of Issett Lake. Thawing was not in evidence at this time.

PHOTOGRAPH 87 - An inundated white birch forest in the Rat River flood plain. The inundated forest is presently in the early stages of hygrophytic succession. Bog bean, a hydrophyte, has presently colonized the open water. Under natural successional conditions, this flood plain will again be colonized by shrubs and trees.

FLOOD PLAIN ECOSYSTEM - CYCLIC PROGRESSION

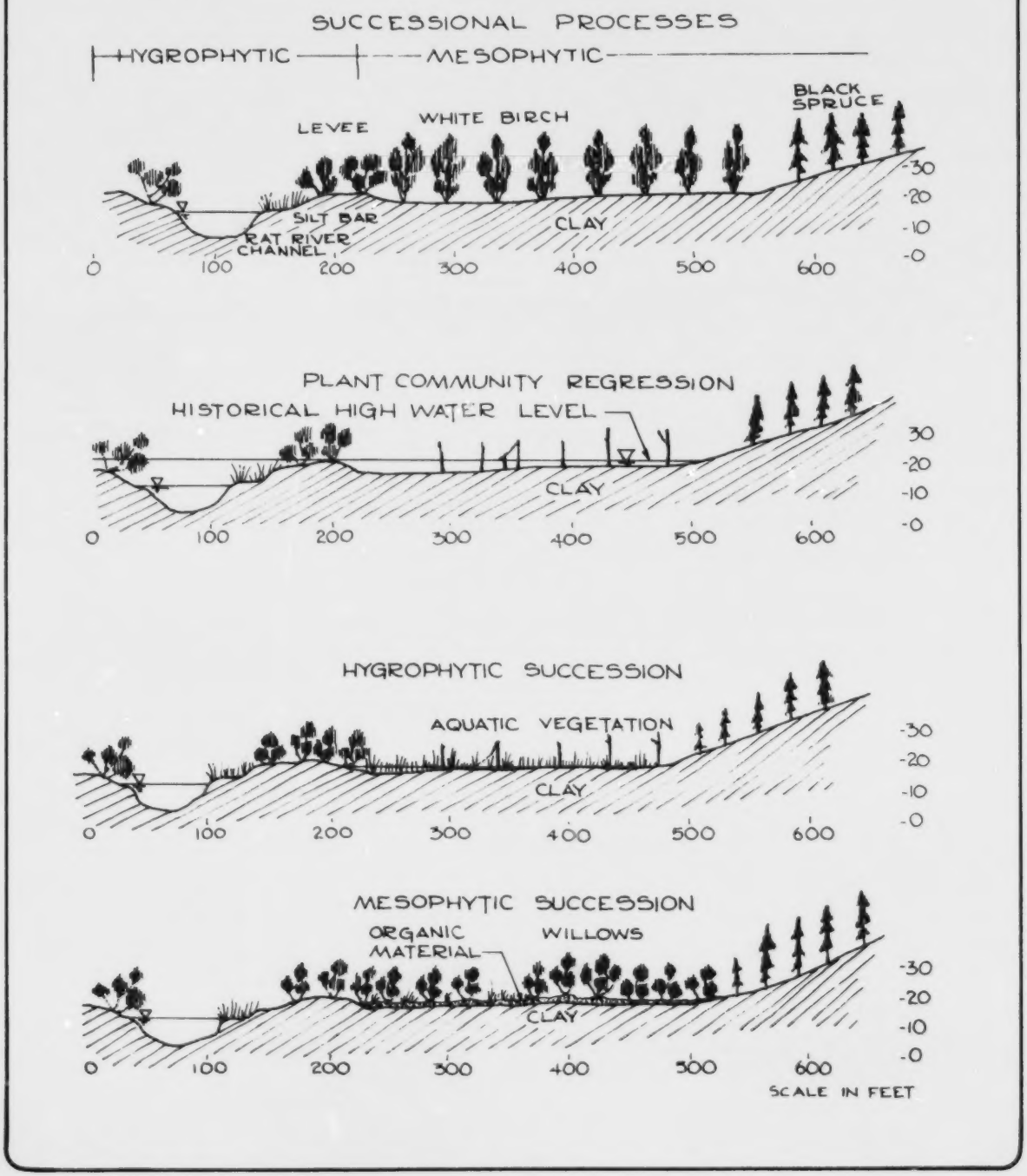


FIGURE 85

Reach 2R: Inundated areas throughout this reach are greatest along the stream and rivers feeding into the Rat River. Generally the backshore slopes of the northern channel segments of Reach 2 are mildly to moderately inclined with a thick overburden while the southern channel segments are steeper with little overburden. For the most part, the inundated acreage is greatest in the northern portions of the reach.

Sedge Communities are limited in extent throughout this reach. The present communities are restricted to the tributary water areas of the Rat River. Collapse scars are apparent in the area, however, they have been included in the Treed Muskeg acreage.

Treed Muskeg with Permafrost is widespread throughout the northern channel sectors but diminishes in occurrence in the southern areas. Treed Muskeg in both pure stands and interspersed with collapse scars is common to all portions of the channel backshore.

Bedrock Outcrops and Clay Overburden become prevalent in the souther nel portion.

Inundated acreage between Pemichigamau Lake and Rat Lake has been included in the Rat Lake figures while the channel area south of Notigi has been included in the Notigi Lake figures.

Reach 3R: Each of the lakes and river areas will be discussed separately.

Karsakuwigemak Lake: Inundated acreage is greatest in the areas due east of the lake along the tributary stream leys. The entire Sedge Community acreage is located within this area.

Throughout the inundated area, sites of poor drainage and low relief consist of a combination of Treed Muskeg and collapse scars.

Treed Muskeg with Permafrost is widespread particularily along the western shoreline areas. Clay Overburden is restricted to the areas of moderate relief and consequently supports the best tree growth in the area. As would be expected, Bedrock Outcrops are sparse and localized.

A localized sand deposit exists along the north lakeshore of the inlet at the 850 foot elevation. The materials in this general area are felt to originate from a nearby esker. At the time of the field season, this overburden was found to be permafrosted and thawing due to the removal of treed cover.

Pemichigamau Lake: Most of the inundated area on Pemichagamau exists along the inlet-outlet areas and the east-west extremities of the lake. Areas adjacent to streams consist of sedge communities, primarily fens, while other inundated terrain consists of a mixture of Treed Muskeg, collapse scars and Treed Muskeg with Permafrost. A considerable amount of bedrock occurs in the backshore area of the exposed bedrock shorelines while clay overburden exists in back of the protected bedrock shorelines. Open water surfaces in the backshore area are small in comparison to other lakes.

A stretch of backshore area along the easterly shoreline is characterized by a blanket bog. Normally, Treed Muskeg would not develop on a moderately sloped bank, however, the high moisture regime of the backshore area allowed for the establishment of such cover.

Rat Lake: The inundated area is far greater along the north-central and extreme north-western portions of the lake. Flooding of other areas is restricted to valleys and bays both of which are predominantly Sedge Communities.

Generally the inundated area consists of a variety of coniferous and deciduous trees on clay hummocks with Treed Muskeg and collapse scars in the low, poorly drained areas. The majority of the well drained Clay Overburden sites are likely permafrosted.

In this area, occurrence of permafrosted muskeg is localized due to the contrasts in topography. Generally the inundated area is either moderately sloped and well drained or else too low and saturated to be permafrosted.

A large percentage of the inundated area in the central portion of the lake consists of Bedrock Outcrops and Clay Overburden.

The inundated areas at the mouth of the Suwannee River were included within the Rat Lake figures.

Suwannee River Area: The major portion of the inundated area consists of a mosaic of Treed Muskeg and collapse scars. Any open bodies of water that may have existed in the past has completely grown over with hydrophytes. Areas defined as Sedge Communities are restricted to portion of the river.

Permafrosted Treed Muskeg is of a low occurrence in the poorly drained saturated areas. Materials supporting the best tree growth are along the Clay Overburden areas of the channel proper. In this entire area there is a distinct absence of Bedrock Outcrops.

Reading River Area: Inundated acreages are greatest in the backshore areas of the channel as most of the lakeshore area is of a moderate relief. The inundated terrain consists of a variety of Sedge Communities, fens and collapse scars, Treed Muskeg and Treed Muskeg with Permafrost. The area contains few Bedrock Outcrops and no recognized Clay Overburden sites.

Mynarski Lakes: The inundated terrain is restricted in these lakes to the low bays and tributary area. The Sedge Communities are primarily fens while the forested land is almost entirely Treed Muskeg.

Misinagu Lake: Inundated acreage here is exceptionally low due to the overall steep topography. In this case areas to be inundated are primarily Treed Muskeg.

Notigi Lake: On Notigi inundated areas can be found in all backshore areas except along the extreme west shore where the terrain is fairly steep.

Inundated areas consist of a mosaic of large fens and Treed Muskeg interspersed with collapse scars. The Clay Overburden and Treed Muskeg with Permafrost exists only in localized areas while Bedrock Outcrops are throughout most of the area.

Future Shoreline Areas: The Notigi Reservoir shoreline at the 850 foot contour is as shown in Figures 80 to 83. Mileages as per shoreline type are shown in Table 9. In many instances the new shoreline is not located precisely in the Figures due to the inadequate contour information and future water level data. At levels

higher than those shown in the Figures there will likely be little change in the predicted shoreline type.

A drop in water levels, particularly in Reach 1, will place the new shoreline in a terrain typically flatter than that of the higher elevations. The milder slopes and consequently poorer drainage results in a transition in plant communities. Trees are reduced in size and a substantial organic layer builds up. At these lower elevations, portions of the shoreline will fall within Treed Muskeg Shoreline Areas (Type A) rather than Clay Overburden Shoreline Areas (Type B) and Glacial Drift Shoreline Areas (Type D). The occurance of Organic Terrain In Valleys (Type C) will not be affected by reduced levels.

Areas predicted to evolve into Shorelines in Coarse Grained Materials (Type 22) typically fall within a glacio-fluvial deposit. The extent of these coarse materials is uncertain. Therefore, Clay Overburden Shoreline Areas (Type B) or Treed Muskeg Shoreline Areas (Type A) will likely be realized in areas classed as Type 22.

The bedrock and bedrock control shorelines (Type 11, 13, 14 and 15) will likely remain as such due to their location. Regardless of the final water level elevation these shorelines will be exposed to wave and/or current action thereby evolving into one of these bedrock shoreline types.

In Reaches 2 and 3, the overall effect of a lower water level would be to reduce the occurrence of Type A and B shorelines and increase the Bedrock and Bedrock Controlled Shoreline distances. Type C shorelines would remain much as they are shown.

TABLE 7

SOUTH BAY TO NOTIGI

Natural Shoreline Types (miles)

Reach	Classification 11	12	13	14	15	21	22	23	24	25	26	27	28	31	Total
Reach 1R															
Issett Lake								2.7					4.2		6.9
Rat River			4.0					2.8					34.7		41.5
Total			4.0					5.5					38.9		48.4
Reach 2R															
Karsakuwigamak to Pemichimagau			3.2					2.0							5.2
Pemichimigau to Rat Lake			4.1	2.5				3.6					1.9		12.1
Rat to Misinagu			29.5	12.6				0.9					5.4		48.4
Misinagu to Notigi		1	7.4	2.2				7.0							16.6
Notigi to Control Structure			0.4	6.8				4.3					0.3		11.8
Total		1	44.6	24.1				17.8					7.6		94.1
Reach 3R															
Karsakuwigamak Lake		1.2	9.9	1.3				3.5					4.9		20.8
Pemichigamau Lake			16.4	9.6				3.0					1.2		30.2
Rat Lake		0.2	116.4	8.0				2.9					12.0	7.7	147.2
Suwannee River Area								11.9					1.6	5.8	19.3
Reading River Area			26.9	1.0	0.3				18.9		0.3		7.1		54.5
Mynarski Lake			12.4	7.4	16.0				3.3		5.4		1.9		46.4
Misinagu Lake			8.7	1.0									0.4		10.1
Notigi Lake		2.2	15.9	6.6				0.6					11.7		37.0
Total		3.6	206.6	34.9	16.3			21.9	22.2		5.7		40.8	13.5	365.5

TABLE 8

NOTIGI RESERVOIR

South Bay to Notigi

Inundated Terrain (acres)

Reaches	Types			Totals	Natural River and Lake Water Surface Area	
	Sedge Communities	Forested Land	Backshore Water Bodies			
Reach 1R						
Reservoir Channel	3,834	28,068	2,662	34,564	Issett Lake	475
					Rat River	639
Sandy Lake Area	7,412	14,574	4,127	26,115		
Totals	11,246	42,642	6,789	60,679		1,114
Reach 2R						
Karsakuwigamak to Pemichimagau	199	1,317	8	1,524		187
Pemichimagau to Rat Lake	-	-	-	-		1,788
Rat Lake to Misinagu	658	5,511	418	6,587		4,239
Misinagu to Notigi	-	2,608	4	2,612		473
Totals	857	9,436	430	10,723		6,687
Reach 3R						
Karsakwigamak Lake	472	4,149	128	4,749		4,249
Pemichigamau Lake	381	3,355	8	3,744		5,141
Rat Lake	2,286	18,502	871	21,660		18,323
Suwanne River Area	1,181	4,365	-	5,546		378
Reading River Area	2,326	13,540	1,090	16,956		2,565
Mynarski Lakes	124	3,078	163	3,365		4,641
Misinagu Lake	10	697	6	713		831
Notigi Lake to Control Structure	1,614	14,425	893	16,932		5,049
Totals	8,394	62,111	3,159	73,665		41,177

TABLE 9

NOTIGI RESERVOIR

South Bay to Notigi

Reservoir Shoreline Distances (miles)

Reach	Classification											
	A	B	C	D	11	13	14	15	22	23	27	Totals
Reach 1R												
Reservoir Channel (mainland)	18	57	2	41	1	47	1	8	8		1	184
(island)	1	27		6		25		4				63
Sandy Lake (mainland)	16	18	3	29		7	*	8	17			98
(island)	1	10	*	4	1	8	2		10			36
Totals	36	112	5	80	2	87	3	20	35		1	381
Reach 2R												
Karsakuwigamak to Pemichigamau (mainland)	2	12				2						16
Rat Lake to Misinagu (mainland)	3	18	1		1	57	11	*				91
(island)		6				13	2					21
Misinagu to Notigi (mainland)		9	*			8						17
(island)		2				8		2				12
Totals	5	47	1		1	88	13	2				157
Reach 3R												
Karsakuwigamak Lake (mainland)	7	24	*			13		1	1	1		47
(island)						3						3
Pemichigamau Lake (mainland)	3	14	2		3	12	10	1				45
(island)		4				4						8
Rat Lake (mainland)	4	109	5		1	32	5	8				164
(island)	2	55	1			69	4	3				134
Suwannee River Area (mainland)		35	1									36
Reading River Area (mainland)	16	66	3		*	17		8				110
(island)	4	40				16		4				64
Mynarski Lake (mainland)	9	30	1			7	1	1				49
(island)		2				2		*				4
Misinagu Lake (mainland)		3				8		1				12
(island)		*				2						2
Notigi Lake (mainland)	2	79	2		2	51	1	27				164
(island)		10				18	1	4				33
Totals	47	471	15		6	254	22	58	1	1		875

* distance less than half a mile

6.2.2 WATER LEVELS AND FLOWS - SOUTH BAY TO NOTIGI: Figure 86 illustrates the natural and regulated monthly maximum, median and minimum flows at the site of the Notigi Control structure. In the natural state, Rat River flows are the highest in early summer, then gradually drop to mid-winter lows. Regulated discharges will be much higher than natural discharges because of diversion flows and will rise from lowest values in early-summer to late-summer and early-winter highs near 30,000 cubic feet per second. During the rest of the winter, discharges will be between 17,000 and 30,000 cubic feet per second.

Short-term fluctuations in discharge will be more severe with regulation. Monthly increases in discharge will generally be the rule from July through November, and will normally be less than a 5,000 cfs rise. Maximum fluctuation during these months may on occasion exceed 5,000 cubic feet per second. Discharge decreases of 6,000 cfs or less will be frequent during February, March, April and June, and may on occasion exceed 20,000 cfs during March and April (once in 25 to 100 years). During January and June rises will be slightly more frequent than drops, and will rarely be greater than 10,000 cfs. By comparison, natural monthly fluctuations are always less than 5,000 cfs, with rising discharges during April, May and June and generally falling discharges during the other months.

The more significant discharge parameters are outlined in Table 10:

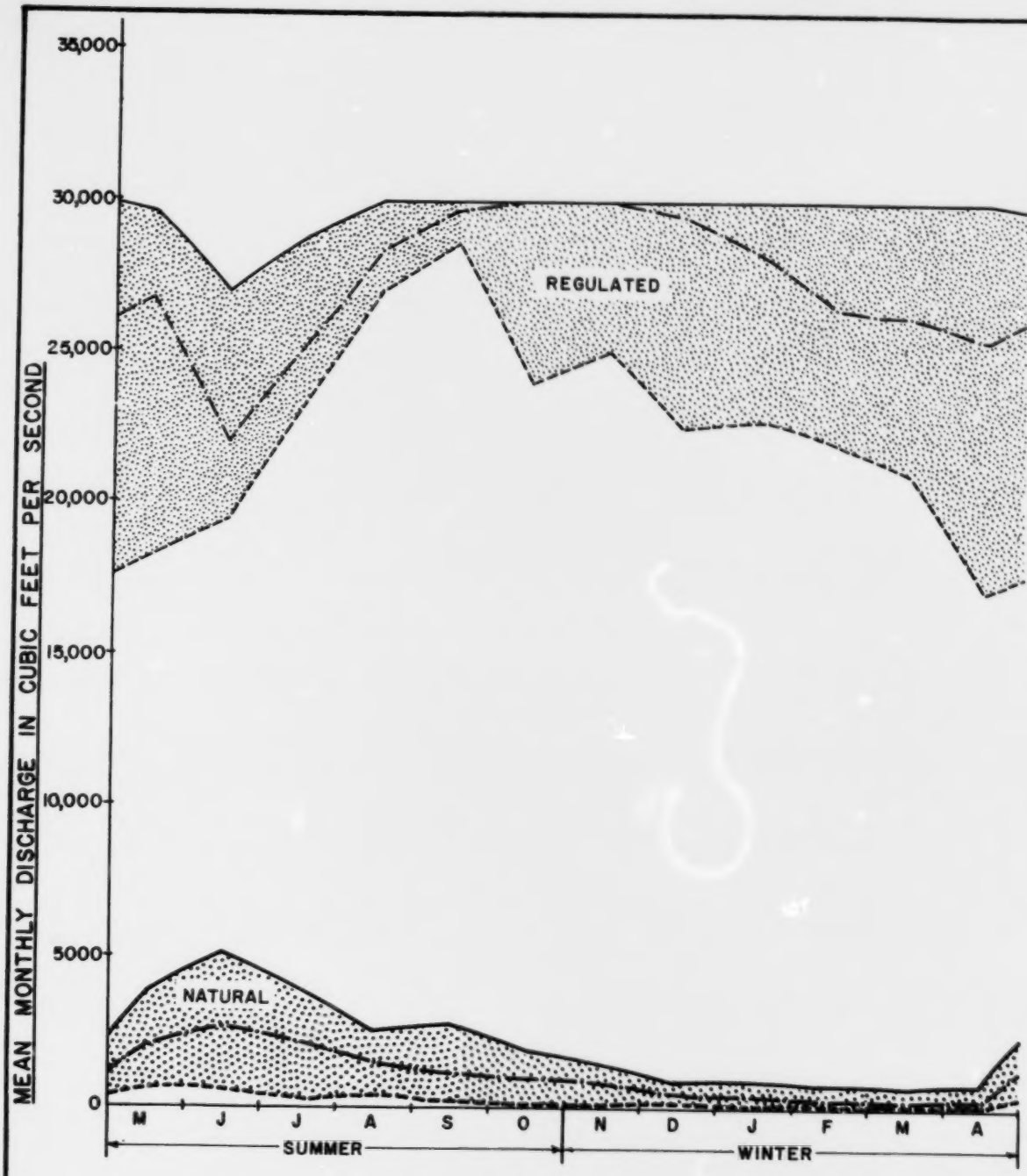
TABLE 10

RAT RIVER FLOWS AT NOTIGI

	Natural	Regulated	Change
Minimum	100 cfs (Jan to April)	17,200 cfs (April)	+17,000 cfs
Mean	1165 cfs	26,900	
Maximum	5800 cfs (June)	30,000 cfs (all except June & July)	+24,200 cfs
Long-term range	5700 cfs	12,800 cfs	+ 7,100 cfs
Maximum monthly fluctuation:			
rise	<5000 cfs (all months)	<20,000 cfs (Mar, Apr and May)	
drop	<5000 cfs (all except May)	<20,000 cfs Mar, (Feb to May, Dec)	

The water levels upstream of Notigi are controlled by the level of Southern Indian Lake and by the volume of flow through the Notigi control structure. If there was no flow through the structure, the water level upstream of Notigi would equalize with that of Southern Indian Lake. If the gates to the structure are opened, the water level upstream drops roughly in proportion to the volume of flow. The drop is a maximum at the structure and decreases to zero at South Bay. The best estimate of levels upstream of Notigi available at the time of writing indicated that for a water level of 847 feet on Southern Indian Lake and a flow of 30,000 cfs at Notigi, the water level immediately upstream of the Notigi structure would be approximately 844.5 feet in summer.

Over the winter months the level at the Notigi control structure would be drawn down to compensate for increased head losses due to ice conditions and also due to a possible slight drawdown on Southern Indian Lake. Thus the level at Notigi may drop from an approximate elevation of 845 feet in December to approximately 838 feet in May. During the ice break-up period in the latter part of May, the level would rise to the open water level over a period of possibly three weeks.



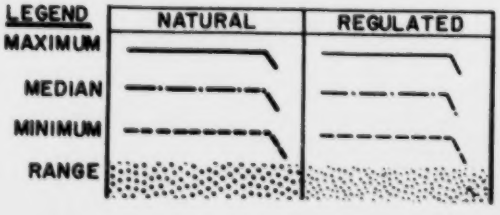


FIG. 86

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
DISCHARGES AT NOTIGI

PREPARED	DESIGN	SUBMITTED		SCALE	DATE	SHEET	FILE NO.
L.B.	S.P.	DATE Jan '74	DATE	AS SHOWN	JAN/74	11 OF 58	61-1-1025
	CHECKED F.P.						

6.2.3 IMPACTED STATE CONDITIONS - SOUTH BAY TO NOTIGI:

Existing Shorelines - Upon flooding, the vast majority of the existing shorelines will be inundated and the impact upon them will be of no consequence in determining the ultimate state of the reservoir shoreline. Exceptions to this being along the Bedrock and Bedrock Controlled Shorelines exhibiting moderately to steeply inclined backshore areas. In this case, the impact is as described under "Impact Process Statement for Shorelines" in Section 5.4.1.

Future Shorelines - The future shorelines, as predicted by this study, are shown in Figures 80 to 83 and as listed in Table 9. Although in most cases, the reservoir shoreline is far removed both horizontally and vertically from the natural shoreline the ultimate reservoir shoreline configuration is predicted with a certain degree of certainty. This is due to the existance of Old Lake Notigi strandline. The importance of this phenomenon is as described in Section 6.2.1.

Possible changes in shoreline types at lower elevations than those shown in Figures 82 to 83 are as discussed in 6.2.1 under "Future Shoreline Areas."

Reach 1R: Discussion of the impact on Reach 1 will be divided to cover the channel area from South Bay to Karsakuwigamak and the chain of lakes west of Issett Lake which will be referred to as the Sandy Lake Area.

The water level rise from the natural mean to the 847 contour is approximately 25 feet in the reservoir channel (elevation 822 to 847) and 15 feet in the Sandy Lake Area (832 to 847).

Under reservoir conditions the Sandy Lake Area will consist of 134 miles of shoreline. The ultimate state of shoreline areas (Types A, B, C, & D) is as discussed under Impact Process Statements Section 5.4.2. Granular shorelines (Type D and 22) occupy a significant percentage of the total shoreline area (45%). The development of the granular beaches (Type D) will in part be a function of the wave action and materials present. Formation of a beach will depend upon, the depth of water, the number of standing trees and floating peat matts in the offshore area. Type 22 beaches will be formed along the southern shore of Sandy Lake due to the close proximity of the local eskers to the existing lakes and the sporadic distribution of the stunted spruce in the offshore area. Low in occurrence, the bedrock shorelines (Types 11, 13, 14 and 15) will be realized early in the adjustment period.

The reservoir channel of Reach 1 will contain 247 miles of shoreline at the 850 foot contour in comparison to the natural state shoreline distance of 48 miles. The ultimate shoreline configuration of Type A and B is questionable due to the extent of clay overburden in this area. Type D shorelines are confined primarily to the Missipakiow River area. Shorelines that were mapped as bedrock control types exhibited exposed bedrock or else were headland situations and will undoubtedly evolve into bedrock shorelines, particularily Type 13. These bedrock shorelines are expected to stabilize within a thirty year period.

The ultimate configuration of the newly created island in the channel will largely depend upon the elevation of the

island and thickness of the overburden. Many of the lower islands are expected to disappear as the overburden is eroded away. It is likely that a few reefs may be formed as the overburden is washed off. The types of eroded islands expected to occur will be similar to those of Sipiwesk Lake (Photograph 88).

Along portions of the channel, Manitoba Hydro has undertaken a forest clearing program for hydraulic purposes, as standing trees will impede the flow of water through the channel. Consequently, the channel from South Bay to Issett Lake was cleared of 473 acres. Felled trees were cut, piled and burned. The number of acres from Issett to Karsakuwigamak that were cleared was 9,400; this was a slash operation. This clearing will do little to enhance the shoreline stabilization processes over most of the channel as it does not extend up to the new shoreline area. Channel clearing north of Karsakuwigamak will, however, speed up the shoreline stabilization process. With the removal of the trees, the erosional and plant colonization processes will occur sooner. An esker in the immediate vicinity will likely form part of the new shoreline.

PHOTOGRAPH 88 - Sipiwesk Lake, flooded 1960. Water level rise-eight feet. Islands within the reservoir are disappearing as the overburden erodes. The undercut vegetation reduces the effect of wave action at the toe of the clay bank.

Reach 2R: The upper portions of the Rat River channel will be flooded by about 32 feet while the lower portions will be flooded by 50 feet. There will be a drop in water levels of about two feet (847 - 845) under normal ponding conditions from Issett Lake to Notigi forebay. Although the vertical level of flooding increases further south, the horizontal extent of flooding decreases due to the steeper terrain in the lower portion of Reach 2R.

In the channel, over half of the shorelines are predicted to become bedrock control. This will likely be realized within the adjustment phase. Type B shorelines along the main channel will also become bedrock controlled once the overburden is eroded away. The same shorelines in the backshore areas of the channel will not achieve a natural shoreline state for some time.

Along the channels, Manitoba Hydro has undertaken to clear approximately 6,900 acres of land in order to facilitate water flows. The cleared channels are from the outlet of Karsakuwigamak to the inlet of Notigi, excluding the lakes. As this was a slash operation, most of the felled trees are expected to collect along lakeshore embayments. Channel clearing to the 850 foot contour will contribute to the shoreline stabilization processes particularly from Karsakuwigamak to Pemichigamau and from Rat Lake to Notigi Lake.

Reach 3R: The vertical extent of the flooding will increase while the horizontal extent will lessen towards the southern portion of the reach. Each lake will be discussed separately.

Karsakuwigamak Lake: Karsakuwigamak will

be flooded by some 32 feet (815 - 847). This will have the effect of increasing the shoreline length from 21 miles to 50 miles. It is suggested that approximately half of the lakeshore will evolve into Type 13. When erosional processes are complete, the Type B shoreline will also become bedrock control shorelines. Shoreline evolutionary processes within the eastern backshore areas of the lake will be severly reduced; consequently, they will not achieve a bedrock control shoreline for some time.

Pemichigamau Lake: Pemichigamau Lake will be flooded comparably to Karsakuwigamak Lake. The shoreline length will increase from 30 miles to approximately 53 miles depending on where the beginning of the outlet is designated. It is anticipated that the east and west arms of the lake will achieve a bedrock control shoreline early in the adjustment phase as most of the flooding along the areas is contained within the natural shoreline backshore area. Shoreline erosional processes will take longer around the inlet and outlet portions of the lake where the overburden will not be eroded as quickly.

Numerous overburden islands will be created; their ultimate configuration will be similar to that discussed in Reach 1.

Rat Lake: Under a 33 foot water level increment (814 to 847) the shoreline distance on Rat Lake will be increased from 147 miles to 298 miles. Although the flooding is contained along most of the shorelines, the low valleys will be flooded extensively, substantially increasing the total shoreline mileage. The large number of newly created islands also contribute to a greater overall distance.

Under reservoir condition, Rat Lake will consist of a maze of islands. Many of the smaller islands are contained within the northern sector while the southern sector contains the larger islands. The ultimate state of the low smaller islands will likely be as discussed in Reach 1R of this section.

The predicted bedrock control shorelines will be established early within the adjustment phase. On these steeper slopes the shoreline recession will be in the order of twenty to thirty feet until bedrock is reached. In general, the Type B shorelines are not as well exposed, therefore, stabilization processes will take longer. Along these shoreline the erosion rate is slower and horizontal recession greater. Evidence of Old Lake Notigi would suggest that bedrock shorelines will ultimately be formed along most of the newly created Rat Lake shoreline.

Suwanee River Area: Due to the low topography and uncertain contours, the exact length of the shoreline within the flooded valley is unknown. However, 36 miles of shoreline along the 850 foot contour were measured at the point beyond the natural fen shoreline. This may or may not represent what will actually be formed. All other shoreline distances were included in the Rat Lake figures.

The ultimate shoreline configuration is uncertain due to the thick deposits of clay typical of the area. Shoreline processes will undoubtedly be slow due to the poor exposure and the volume of inundated trees. Natural state shorelines will not be achieved by the Fifty-Year Time Frame.

Lower contours than those mapped will

place most of the shoreline in the western portion of the river valley in Type A and C shoreline areas.

Reading River Area: The natural state shoreline consists of 55 miles while the reservoir shoreline will be roughly 174 miles. The greatest difference will be around the river channel itself, the lake section will likely be affected in a manner similar to Rat Lake.

Under reservoir conditions, the channel will take on the appearance of a large lake interspersed with many islands. The channel area will become part of Upper Mynarski Lake. Since most of the channel area is low lying and poorly exposed, a natural shoreline will not likely be achieved within the Fifty-Year Time Frame. As in the case in the Suwanee River area, the exact location of the new shoreline is not known.

Mynarski Lakes: The Mynarski Lakes shoreline distance will increase from 46 to 53 miles. The change in water level in the Lower Mynarski Lake will be about 20 feet (827 - 847). The majority of the new shorelines will be contained within the backshore typical of the existing shoreline type. Bedrock control shorelines will likely be achieved along most of the shorelines within the adjustment period.

Misinagu Lake: The Misinagu Lake water level increment will be approximately 34 feet (813 - 847). Due to the moderate steep slopes, the shoreline distance will only increase four miles. Most shorelines will stabilize early in the adjustment phase.

Notigi Lake: The Notigi Lake water level increment will be 53 feet (794 - 847). The shoreline distance from the lake to the control structure will change from 49 miles to 197 miles. The marked shoreline increase is due to the extensive flooding that will occur at the southern and far eastern portions of the lake. A stable shoreline will be achieved along the western and southern portions of the lake area within the adjustment period. The west shore has a steep slope while most of the southern area has been cleared of trees to the 850 foot contour.

Manitoba Hydro has undertaken to clear some 4,440 acres in this immediate area. This cut, pile and burn operation was done for reservoir management and asthetic purposes. This clearing will facilitate the shoreline stabilization process in the area.

The shorelines within the inundated valleys in the eastern portion of the lake will not achieve a natural state configuration within the Fifty-Year Time Frame.

Inundated Terrain: Inundated terrain is shown in Figures 80 to 83 and in Table 8. The impact on Inundated Terrain areas is as discussed in Section 5.4.3, "Impact Process Statements for Inundated Terrain". Each of the reaches will be briefly discussed.

Reach 1R: In the Sandy Lake area a large proportion of the Sedge Communities, in particular the floating fens and bogs will rise with the incremented water level. Collapse scars overgrown with sedge will likely also rise. This floating material will likely be contained within the lake area due to the low level of flooding, the volume of inundated trees restricting movement and the narrow nature of the outlet.

In general, the larger communities are expected to revert back to a younger sere supporting emergent hydrophytes. The large fen north of Pear Lake will likely be influential in forming a Fen Shoreline along most of the north shore of that area. Floatation of Treed Muskeg islands are not expected to occur. The emergent and submergent aquatics that inhabit the three existing lakes will be eliminated.

With a maximum water level rise of 15 feet, the inundated forested areas will contain a considerable amount of dead standing trees. This will be particularily evident along the portions north of the island.

The reservoir channel itself contains a higher proportion of forested land than the Sandy Lake Area. None of the impacted Sedge Communities are as large as those of Sandy Lake. The majority of Sedge Communities expected to rise will originate from collapse scars. Those that rise will likely float down to Karsakuwigamak.

The liklihood of floating Treed Muskeg islands being created is greater along this channel than in any other portion of the reservoir. With the expected water level rise and channel velocities, such islands could float into Karsakuwigamak.

In the channel backshore areas, bodies of water will remain congested with dead standing trees throughout the adjustment period.

The trees that were slashed as part of a Manitoba Hydro clearing program will rise with the water levels. This debris will either collect in channel embayments or float to the lakes.

Reach 2R: As the Sedge Community acreage is low throughout the reach, little floatation is expected to occur. The total acreage of inundated forest will be low due to Manitoba Hydro's clearing program. The greatest proportion of standing flooded trees will be in the backshore areas where the water flows and ice movements will have little effect.

Reach 3R:

Karsakuwigamak Lake: Any significant sedge matt floatation will only occur within the low flooded areas east of the lake. Impacted matts will remain contained within the area and the extent of flooded trees will be greatest along stream valleys. Such valleys will remain congested with standing trees for a 50-year period. Localized permafrost sites were recognized along sectors of the north shore; this muskeg may or may not float with the rising levels. If they rise, the islands will move to the down-stream portions of the reach.

Pemichiganau Lake: The sedge community at the extreme east arm of the lake is expected to rise with the water levels. Easterly winds will likely move the floating matts to the central portions of the lake where the channel currents may move them downstream to Rat Lake. Smaller sedge matts will be generated from the extreme northern and southern portions of the lake. It is in these areas that most of the trees will be inundated.

Several permafrosted Treed Muskeg areas were identified along the channel between Pemichigamau and Rat Lake. The reaction of these to rising waters is once more uncertain.

Rat Lake: Quite a few large fens will

be generated from the low lying inundated areas in Rat Lake. Most of these will likely remain contained in the general area from which they originated.

The largest percentage of inundated trees will be in the north and western portions of the lake. It is in these areas that the smaller floating sedge matts will be generated.

Suwannee River Area: The large fen along the river outlet is of special concern in this area. This particular fen may rise with the new water levels and form portions of the new shoreline in the immediate area.

Although low in relief, the backshore area will not contain the volume of inundated trees as indicated by the forested land acreage. The majority of sedge collapse scars are expected to rise with the new water levels. Over most of this area a new natural state shoreline will not develop within a fifty year period.

Reading River Area: The low lying areas contain a variety of sedge communities, most of which are expected to rise with the water levels. The majority of the impacted matts will likely remain confined in the general area.

Inundated forested land will remain congested with dead standing trees.

Misinagu and Mynarski Lakes: Both these lakes contain relatively little inundated area. Most of what will be flooded is part of the backshore area of the natural state shoreline. Low protected embayments and stream valleys will remain congested with standing flooded trees.

Notigi Lake: Most of the inundated sedge communities at Notigi are in the backshore areas of the reservoir. A portion of the matts originating from these areas will undoubtedly float to the dam. As much of the muskeg is interspersed with collapse scars, the forested land acreage is high. The occurrence of flooded trees in the eastern portion of the lake will retard the shoreline stabilization processes at the new water line. Shoreline formation processes will be speeded up along the southern shorelines where clearing operations were undertaken.

6.2.4 SUMMARY STATEMENT - SOUTH BAY TO NOTIGI: The Rat River drainage system from South Bay to Notigi includes the lakes: Issett, Karsakuwigamak, Pemichigamau, Rat, Mynarski, Misinagu and Notigi, and inflowing river systems: Missipakiow, Reading and Suwannee. At its head waters (Issett Lake), the Rat River is of a tranquil winding nature straightening out as it widens and approaches Karsakuwigamak. This upper portion of the river, characterized by the low clay banks and extensive backshore marshes, is within a wide flood plain valley. Channel sections between the lakes are predominantly bedrock controlled and contain steep shores. Here, marsh zones are confined to silt bars.

The lakes along the system are typical of those found anywhere within the Precambrian Shield and contain a greater variety of shorelines than the river shores. Lake shores are predominantly bedrock interspersed with sand beaches and marshes.

After diversion of the Churchill River, water which normally flows down the Lower Churchill River to Hudson Bay will be redirected to flow via the Rat-Burntwood system into the Nelson River and into

Hudson Bay. The Rat River which normally has a mean discharge of 1,165 cfs will carry 26,900 cfs after the diversion. A dam at Notigi will allow for regulation of discharges down the remainder of the diversion route. The impounding of the water to the 847 foot level will create a reservoir which will extend from Notigi Lake to South Bay on Southern Indian Lake. The Notigi Reservoir water surface elevation will be approximately 25 feet above the normal water level in the upper end of the reservoir and 50 feet above the normal water level in the vicinity of the dam site.

The shoreline of the man-made reservoir will re-occupy an ancient shoreline and lake bed created in post-glacial times. Although the raised water levels will be contained within the vicinity of the old lake shore, thereby lessening the shoreline impact, the diversion and water impoundment will significantly alter the character of the landscape. At the 850 foot contour, approximately 145,000 acres will be inundated. This area includes 114,000 acres of forested terrain, 21,000 acres of wetland-type communities (bogs and fens) and 10,000 acres of backshore water bodies. The figure for forested land is high as much of the area consists of stunted black spruce interspersed with pot holes.

The effects of flooding will be severest along the upper portion of the Rat River from Issett Lake to Karsakuwigamak where the natural river channel distance of 42 miles will be increased to 247 miles. In this area, the Rat River will be changed into a lake characterized by bedrock shorelines and actively eroding clay banks. Protected shorelines such as flooded embayments and stream valleys will remain congested with standing and fallen trees thereby detracting from the asthetics of the shoreline area and interfering with shoreline development processes.

Although the vertical flooding is greater in the lake areas and adjoining channels, the horizontal extent of flooding is lessened due to the steeper nature of the terrain. In this case, the majority of the water-land interfaces will evolve into bedrock shorelines. However, they will achieve a natural state very slowly due to eroded debris and driftwood accumulating and protecting the shoreline. As was the case in the upper reservoir, flooded stream valleys and embayments will not evolve into a natural shoreline within a fifty-year period.

Flooding will reduce the variety of shoreline types typical of a natural waterway and increase the shoreline distance. Marshes and alluvial shorelines will be eliminated and new ones will not be established to any extent within a fifty-year period. The total shoreline distance will be changed from approximately 500 miles to 1400 miles.

Numerous islands will be created under reservoir conditions. Islands, characterized by a thick clay overburden and low relief, will likely erode away, whereas larger bedrock control islands will remain intact.

6.3 CHURCHILL RIVER DIVERSION - NOTIGI TO SPLIT LAKE

6.3.1 NATURAL STATE CONDITIONS - NOTIGI TO SPLIT LAKE:

6.3.1.1 Natural State Conditions - Rat and Burntwood Rivers - Notigi to Split Lake: This portion of the Rat-Burntwood system consists of Wapisu Lake, a short section of the Rat River, Threepoint Lake, and the rest of the Burntwood River System below Threepoint Lake (Figure 87).

Wapisu Lake can be characterized by a general predominance of bedrock shorelines. Small bays between bedrock outcrops, frequently have beaches with a thin layer of sand overlying clay. The Rat River in this region flows tranquilly between clay banks having low relief.

Burntwood Lake marks the headwaters of the Burntwood River. From here to its mouth, Split Lake, is a distance, as the river flows, of 240 miles. The drainage area of the Burntwood and its tributaries is 9,870 square miles. As is the case with the Rat, the Burntwood flows over rocks of the early Precambrian. The river flows within the bed of glacial Lake Agassiz and hence the overburden is of lacustrine origin. Silts and clays predominate but sands occur in local deposits. The relief of this old lake bed is generally low.

Threepoint Lake is characterized by the low shorelines and the several extensive beaches. Wuskwatim is similar in relief though bedrock shorelines are more frequent. Opegano and Birch Tree Lakes are in the middle of deep lacustrine deposits and their shorelines show the effect of continuing erosion. The banks are steep and barren of vegetation. Apussigamasi Lake has rock outcrops and alluvial embayments much like those found on the Rat River.

The channels joining Threepoint, Wuskwatim, Opegano and Birch Tree Lakes and as far as the confluence of the Manasan and Burntwood River have several rapids and falls. Bedrock shorelines are frequent though not continuous. Near the above mentioned lakes and for a few miles above and below Thompson the shorelines are low having fair to poor drainage, and containing many marshy areas. Below Apussigamasi Lake and right to Split lake the valley walls increase in height. Slumping is noticed in several areas. Vertical and horizontal control is maintained by a few bedrock constrictions but elsewhere horizontal control is generally of alluvium.

Permafrost is a common element in the surficial material especially where materials are fine and drainage is poor.

The vegetation cover along the Burntwood is similar to that along the Rat. A wide variety in tree types, understory and ground cover species can be found. The best growth however, is on the well drained mineral soils.

The water in Burntwood accumulates suspended sediments from the many miles of eroding shorelines and as a result the river is somewhat more turbid than the Rat.

A description of characteristic reaches of this portion of the Rat-Burntwood River system follows. These reaches are defined on Figures 88, 89 and 90. The mileages of shoreline types in these reaches are summarized in Tables 11 to 15.

Reach 2R: Reach 2R (Figure 88, Table 11 and 12) covers the portions of the Rat River channels between the Notigi site (Photograph 89) and Wapisu Lake, and between Wapisu Lake and Threepoint Lake. The overburden in this area is

sufficiently deep along the river channel to mask details of the underlying bedrock topography. In these few miles, a combination of Types 14 and 23 constitute the majority of the shoreline.

Type 14 shoreline is most common, being about 13 miles in extent. Overburden in this reach is primarily lacustrine clay, with one local deposit of sand near the outlet of Wapisu Lake. The initial slope is shallow but steepens farther backshore. This is dependent upon the prevalence bedrock. Carex spp; and Salix spp., dominate the shoreline in a zone about 30 feet wide extending some 20 feet into the water. Immediately behind the shoreline zone, a predominantly closed coniferous forest begins with occasional deciduous zones. Picea glauca is predominant. Picea mariana exists in heavy concentrations near the shoreline but thins as the slope increases two hundred feet back. Occasional Pinus banksiana exist on the slope. The deciduous component is made up mainly of Populus tremuloides with some Betula papyrifera. The average height of these trees is 50 - 60 feet. A dense understory consists of Alnus sp., Cornus stolinifera and Juniperus communis. Ground cover and herbs include Aralis nudicaulis, Oxycoccus microcapus, Ledum groenlandicum, Campanula sp., Cornus canadensis, feather mosses and Sphagnum spp.

There are about six miles of Type 23 shoreline in this reach. The shoreline is similar to that described for the Upper Rat River.

The shorelines classified as 13 in this reach are not unlike that in the Upper Rat River. The water-washed zone is usually narrower than average, about 10-15 feet, and is devoid of vegetation. Closed coniferous forest is prevalent behind the exposed bedrock. The dominant species may be either Picea mariana or Picea glauca, but Populus tremuloides, Populus balsamifera and Betula papyrifera are also common. Similar understory and herb communities as described in the previous section exist here on a ground cover of feather mosses and Sphagnum spp. About two miles of shoreline are represented by this profile.

Approximately one mile of marsh exists in one continuous length in an embayment near the outlet of Wapisu Lake. This shoreline is classified as Type 28m.

Reach 3R: Wapisu Lake comprises Reach 3R (Figure 88, Table 11 and 12). This lake is similar to other lakes in the Rat River system, with frequent bedrock promontories separated by gently curved overburden shorelines or marshes.

The most common shoreline material is bedrock, and most frequently it is of low relief or of only moderate slope. Overburden is generally a thin layer of clay. These shorelines are therefore, classified as 13, and comprise some 41 miles. Sparse Carex spp, and Gramineae are present. Closed coniferous forest dominates behind the rock outcrop. Main species are Picea glauca, Picea mariana, Pinus banksiana along with some Populus tremuloides and scattered Populus balsamifera. Alnus sp. dominates the understory in conjuction with Viburnum trilobum, Ledum groelandicum, Arctostaphylos uva-ursi, Aralia nudicaulis, Cornus canadensis, and other associated herbs grow through a thin layer of lichens, feather mosses and Sphagnum spp..

Bedrock-controlled shorelines with alluvial land-water interfaces join the stretches of bedrock. These are generally Type 14. A thin veneer of sand is found on the beach in many locations along Type 14 Shorelines. About 19 miles of this shoreline exists along this lakeshore.

About three miles of shoreline Type 23 occurs in embayments on Wapisu Lake. The only apparent difference between this and other occurrences is that the zone of Populus balsamifera and Salix spp, extends farther from the water's edge in embayments. There is also more likelihood of a beach-like pattern developing.

In conjunction with Types 23 and 14, Classification 28, totalling some three miles is found at the shallow end of embayments.

Reach 1B: From Threepoint Lake to Birch Tree Lake the channels embody similar characteristics and have been mapped as Reach 1B (Figure 88 and 89 and Tables 11 and 12). Alluvial shorelines are found at the exit of Threepoint and at the entrances to Wuskwatim, Opegano and Birch Tree Lakes. The rest of the reach is made up of bedrock outcrops and associated bedrock-controlled shorelines of moderate relief. Drainage is generally good with exceptions along the stretches of alluvium. Vegetation, except where burned over, is dense and heavy. The river is fast with several rapids and falls.

The bedrock shorelines comprise about 17 miles of channel bank. About two miles of this is Type 11 while the remainder is Type 13. That noted as Type 11 is identical to the profile originally described and so requires no comment here. It occurs virtually in one piece along either side of a one mile length of channel.

Type 13 has backshore lacustrine deposits rather than till. Drainage is good. Permafrost is intermittant. The water-washed zone is frequently devoid of vegetation while the backshore is densely forested with conifers being dominant. This shoreline comprises a total of 15 miles.

Occurrences of Types 11 and 13 are frequently separated by a shoreline of Type 14 with occasional backshore outcrops. The overburden is of lacustrine origin consists of clay or silty-clay. A closed coniferous (occasionally deciduous) forest backs a narrow zone of shrubs at the water's edge. About 26 miles of shoreline can be classified as Type 14.

Shoreline Type 23 is found at the outlet of Threepoint Lake and along the inlets to Wuskwatim, Opegano and Birch Tree Lakes. They correspond to the typical description except below Threepoint Lake where a regeneration forest, about 10-15 feet high, of dense Populus tremuloides and Betula papyrifera is typical. Salix spp, and Alnus sp., near the shoreline constitute the understory with numerous Picea mariana seedlings. Equisetum sp., Fragaria Sp., Epilogium angustifolium, Mentha arvenis and associated herbs grow through a thin layer of feather mosses, lichens and Sphagnum spp. Type 23 accounts for 19 miles of river bank in this reach.

The remaining shoreline is Type 28m. The marshes are somewhat wider than those found on the lower Rat River. The zone of Salix is extensive. From the water to the uplands is frequently a distance

of 1000 feet of more. The entire nine miles of Type 28m occur between Threepoint and Wuskwatim Lakes. The major portion of this occurs in a wide, low area just upstream of Wuskwatim Lake.

Reach 2B: Threepoint and Wuskwatim Lakes make up Reach 2B (Figure 88 and 89, Table 11 and 12). Although they are not identical they share the same major characterictics. Basically, their shorelines are bedrock controlled, those on Wuskwatim more so than those on Threepoint.

Type 13 is predominant. About 39 miles of it occurs about equally divided between the two lakes. It is similar to the typical description except that the average relief of the lakeshore is less than along the river.

Types 23 (26 miles in extent) and 14 (11 miles) fill in most of the distances between outcroppings. These are again typical. Type 14 shorelines are of somewhat less relief than average. A large segment of the north and east shore of Threepoint Lake is regeneration forest on Type 23 shorelines. Type 23 shorelines on Wuskwatim Lake are similar to the general profile. About two miles of this classification exist at the mouth of Wuskwatim Brook, and are considerably lower than the general Type 23. Shorelines of this type on Threepoint Lake (19 miles) are frequently lower than the general profile with a dense growth of willows in a zone above the water line.

Beaches are not common along the Burntwood River. There are about six miles of beach profile on Threepoint Lake of Type 22. The beaches are narrow and of a steep but short gradient. The entire lake is quite shallow and Potamogeton spp; is present throughout the Lake.

There is about one mile of marsh-like shorelines, a small amount on each lake but most of it is on Threepoint Lake. It has been adequately described elsewhere. In this case the marshes (Type 28m) have developed in small bays at the mouth of small tributaries. Thus, they are of no great extent in either direction.

Reach 3B: Reach 3B is short and includes the channel between Birch Tree Lake and Apussigamasi Lake (Figure 89, Tables 11, 13 and 14). With one or two minor exceptions it is a reach which shows low relief with occasional outcroppings. The exception occurs at Manasan Falls (Photograph 90) where bedrock is the dominant bank material. Another outcrop occurs at Thompson. Horizontal control is mostly alluvial throughout this reach.

Type 23 is the dominant profile in this reach comprising about 20 miles of shoreline. The alluvial shoreline is backed by lacustrine deposits. The foreshore vegetation is typical shrub while the backshore is normally closed coniferous (Picea mariana) forest. Occasionally the backshore is a closed deciduous (Populus spp.) forest. Drainage is usually moderate but frequently only fair.

Somewhat less than two miles of river bank are classified as Type 14. All of this type occurs in the vicinity of Manasan Falls flanking the ridge associated with the Falls. Type 14 below the Manasan Falls is much higher than that above. Vegetation is typical for this classification.

About two miles of outcrop shorelines exist in this reach. They are concentrated at two points along this stretch. They are fairly low except at the edge of Manasan Falls. The water-washed zones are free of vegetation. The backshores are well-drained and heavily treed in typical fashion.

Reach 4B: Reach 4B includes Opegano and Birch Tree Lakes (Figure 89, Tables 11 and 13). These lakes are like pot-holes and sit on deep, level lacustrine deposits. Both lakes are very shallow, and little more than widenings in the river. The width of the lakes is great enough for wave action to play an important part in the evolution of the shorelines. Erosion of the lakeshores increases the sediment load in the river substantially. The shallow depth of these two lakes, especially near the shore is an important feature. By absorbing a portion of the wave energy, the offshore shallows provide for lesser erosion rates of the unstable banks than would other-wise occur.

The predominant shoreline here is Type 25. Wave action is responsible for continued erosion and extensive slumping of the twenty to thirty-foot high banks. Melting permafrost is often a contributing factor. The banks are very steep and erosion inhibits vegetative growth. On the uplands is an open coniferous forest with Picea mariana being dominant. A heavy organic layer is also typical. There are about 17 miles of this shoreline on the two lakes. The following profile shown in Figure 91 was taken at one of these sites on the west shore of Opegano Lake, and is typical of occurrences in this reach.

Three miles is the extent of bedrock predominated shoreline on these lakes. All of it is of Type 13 and has been adequately described in the drawn profile.

Included also in this this reach are two miles of Type 14. This occurrence is similar to others on the Burntwood. It occurs in two stretches on the southeast shore of Birch Tree Lake.

Type 23 also exists in this reach primarily on Opegano Lake. There are about three miles of this Type. Details have been explained frequently and need not be repeated here.

There are two miles of Type 28. It occurs primarily at the mouths of small tributaries on Birch Tree Lake and along the northwest corner of Opegano Lake. These occurrences are not as wide as on Reach 1B.

Reach 5B: Reach 5B runs from the upstream end of Apussigamasi Lake to a point 15 miles downstream of the lake (Figure 89 and 90, Tables 11 and 14). The lake itself is little more than a shallow expansion in the river. It is typified by bedrock promontories and deep alluvial embayments. The topography is very similar to that found on the Upper Rat River. The shoreline is bedrock controlled although the overburden in the embayments tends to belie this fact. As on Opegano Lake, offshore shallows are important dissipators of wave energy, and are partially responsible for the present stability of these overburden shorelines. Erosion of the banks becomes an important factor on the lower half of this reach (Photograph 91). Marshes are infrequent although aquatic vegetation is common.

The 28 miles of Type 13 bedrock shorelines are the most common classification on Apussigamasi Lake. The headlands tend to be flatter and have a wider water-washed zone than the other areas. Vegetation is much the same as in the typical cross-section.

Type 23 accounts for about 24 miles of shoreline. It is the major component of the embayment banks found on the lower half of Reach 5. Typical vegetation of Type 23 shoreline is present. The zone flanking the water's edge is fairly narrow. Shorelines of this type in wider areas often show the effects of continuing erosion by wave action.

Steep actively eroding banks, about 5 miles in length, are classed as Type 25. The lacustrine silt and clay banks rise 15 to 30 feet from the water. The foreshore is devoid of vegetation. The backshore, which rises steadily from the face of the eroding bank is covered with either an open or closed coniferous forest, the dominant species being Picea mariana.

About four miles of marshes occur on this reach. This Type 28 shoreline follows its normal pattern. It appears mostly at the mouths of contributing streams.

Two miles of Type 14 shorelines have been mapped in this reach. This shoreline is similar to the typical profile.

Reach 6B: From the downstream end of Reach 5 to the mouth of the Burntwood River in Split Lake is a distance of more than 35 miles (Figure 90 and Tables 11, 14 and 15). This is Reach 6B. The lacustrine deposits are much deeper here than on previous reaches. The river has worn its way through the overburden to the bedrock and the vertical flow is controlled throughout. Horizontal control is usually alluvial except for several small rock outcrops spaced along the route. Slumping shorelines are frequent between bedrock controlled headlands.

The most extensive shoreline type, covering nearly 44 miles is Type 14. The banks are steep and well-drained. The beach normally associated with this shoreline may at times be nonexistent. The bedrock control of the topography warrants its classification as 14 rather than 23, although the distinction is often minor. Much of the riverbank has been burned over and the vegetation is regeneration forest.

Type 25 shoreline is spread along one lengthy stretch near the upper end and several small isolated cusps on the lower end. The backshore slopes more steeply than the typical flat landform. In the backshore, where regeneration forest does not occur, there is a closed coniferous forest. There are about 16 miles of Type 25 shoreline.

Type 13 outcroppings make up seven miles of Reach 6. The outcrops are well spaced and occur on both banks at control sections. Heavier overburden on the back shore is the only characteristic to distinguish it from previous Type 13 shorelines. Vegetation is typical of Type 13.

Type 23 shoreline is rare, comprising only two miles of Reach 6. There are no distinguishing characteristics although the eventual rise to the uplands in the backshore is much greater than is normal for this Type. It is found mainly in two embayments and in all locations it is associated with Type 14.

The usual small section of marsh is found at the back of embayments making up about a mile of shoreline.

PHOTOGRAPH 89 - The Rat River in the vicinity of the Notigi control structure.

PHOTOGRAPH 90 - Manasan Falls on the Burntwood River a few miles above Thompson. This is the site of a future generating station.

PHOTOGRAPH 91 - Eroding bank backshore on Apussigamasi Lake. Note the slump crack.

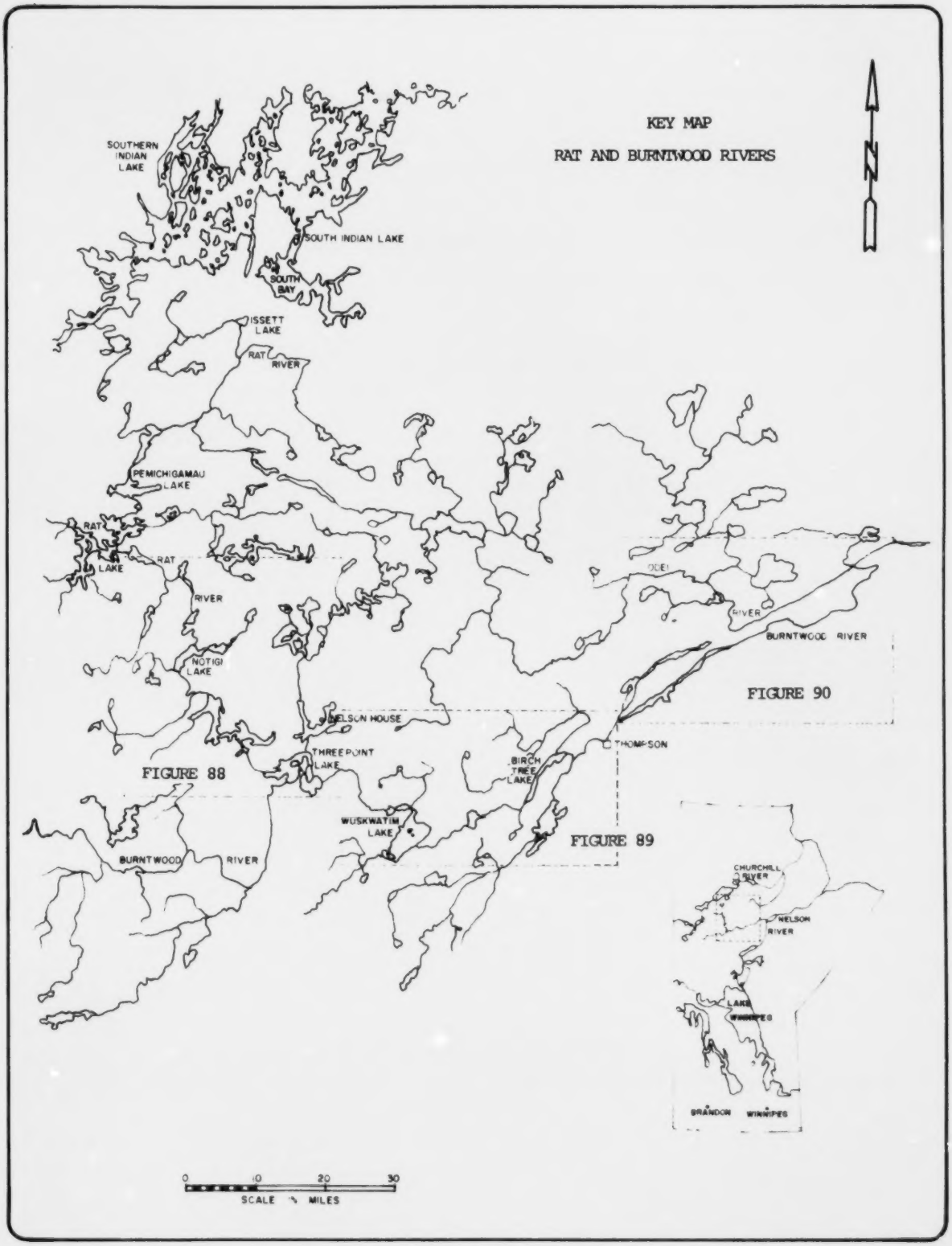

KEY MAP
RAT AND BURNTWOOD RIVERS
N
SOUTHERN INDIAN LAKE
SOUTH INDIAN LAKE
SOUTH BAY
ISSETT LAKE
RAT RIVER
PEMICHIGAMAU LAKE
RAT LAKE
RAT RIVER
NOTIGI LAKE
NELSON HOUSE
THREE POINT LAKE
WUSKWATIM LAKE
BURNTWOOD RIVER
BURNTWOOD RIVER
THOMPSON
BIRCH TREE LAKE
FIGURE 88
FIGURE 89
FIGURE 90
CHURCHILL RIVER
NELSON RIVER
LAKE WINNIPEG
BRANDON
WINNIPEG
0 10 20 30
SCALE MILES

FIGURE 87

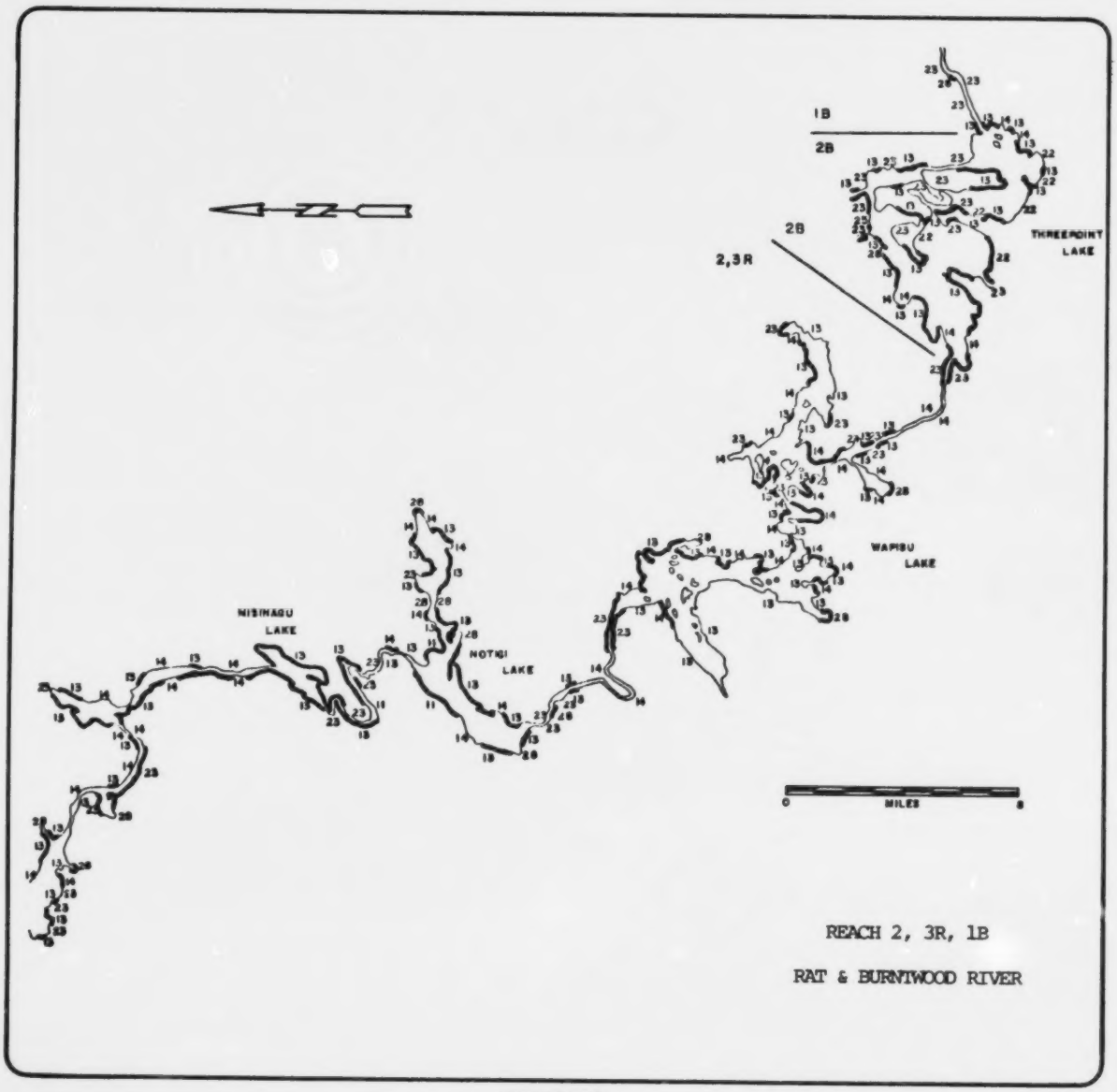

1B
2B
2B
2,3R
THREEPOINT LAKE
WAPISU LAKE
NOTIKI LAKE
NISINAGU LAKE
0
MILES
8
REACH 2, 3R, 1B
RAT & BURNTWOOD RIVER

FIGURE 88

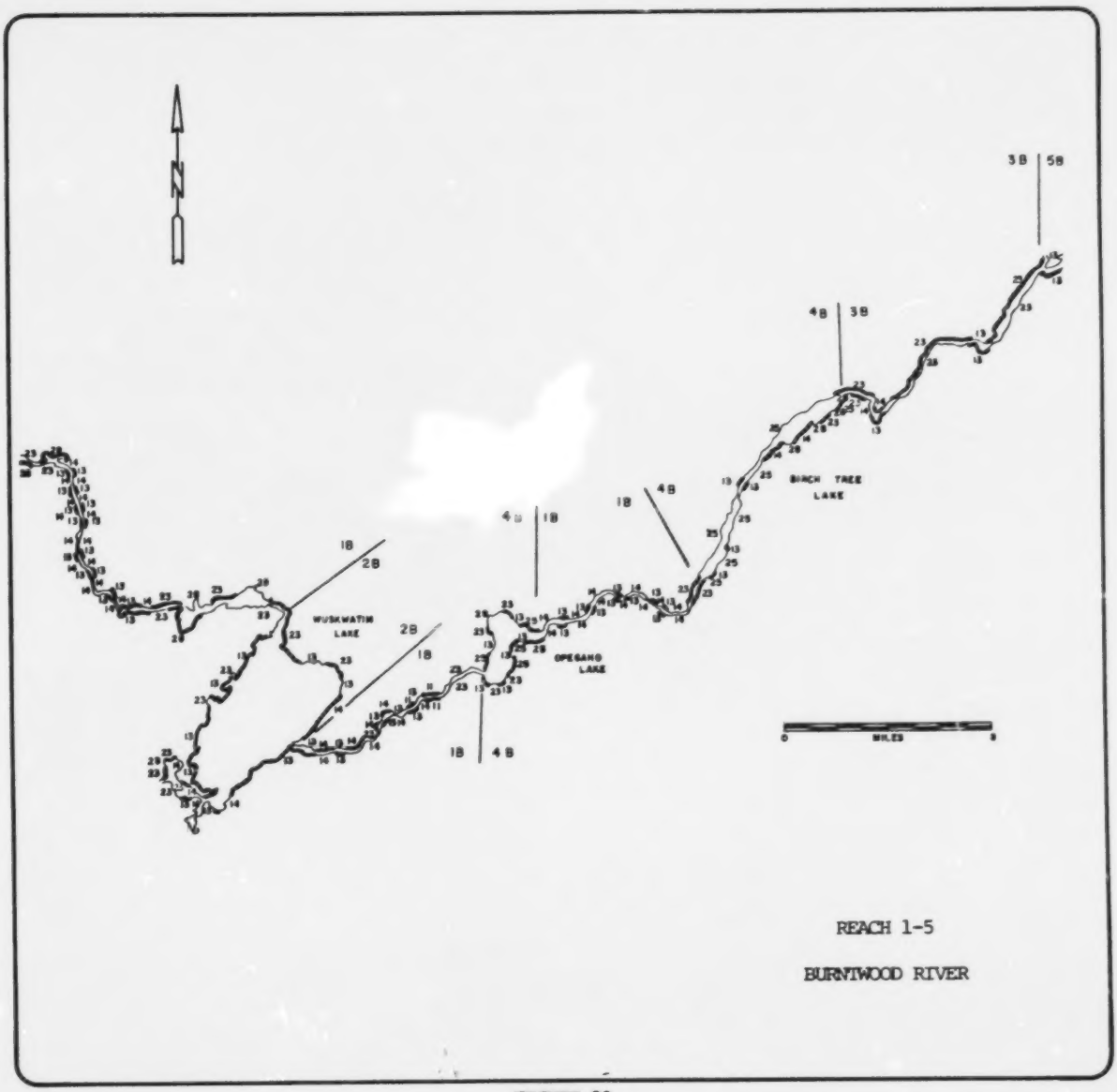
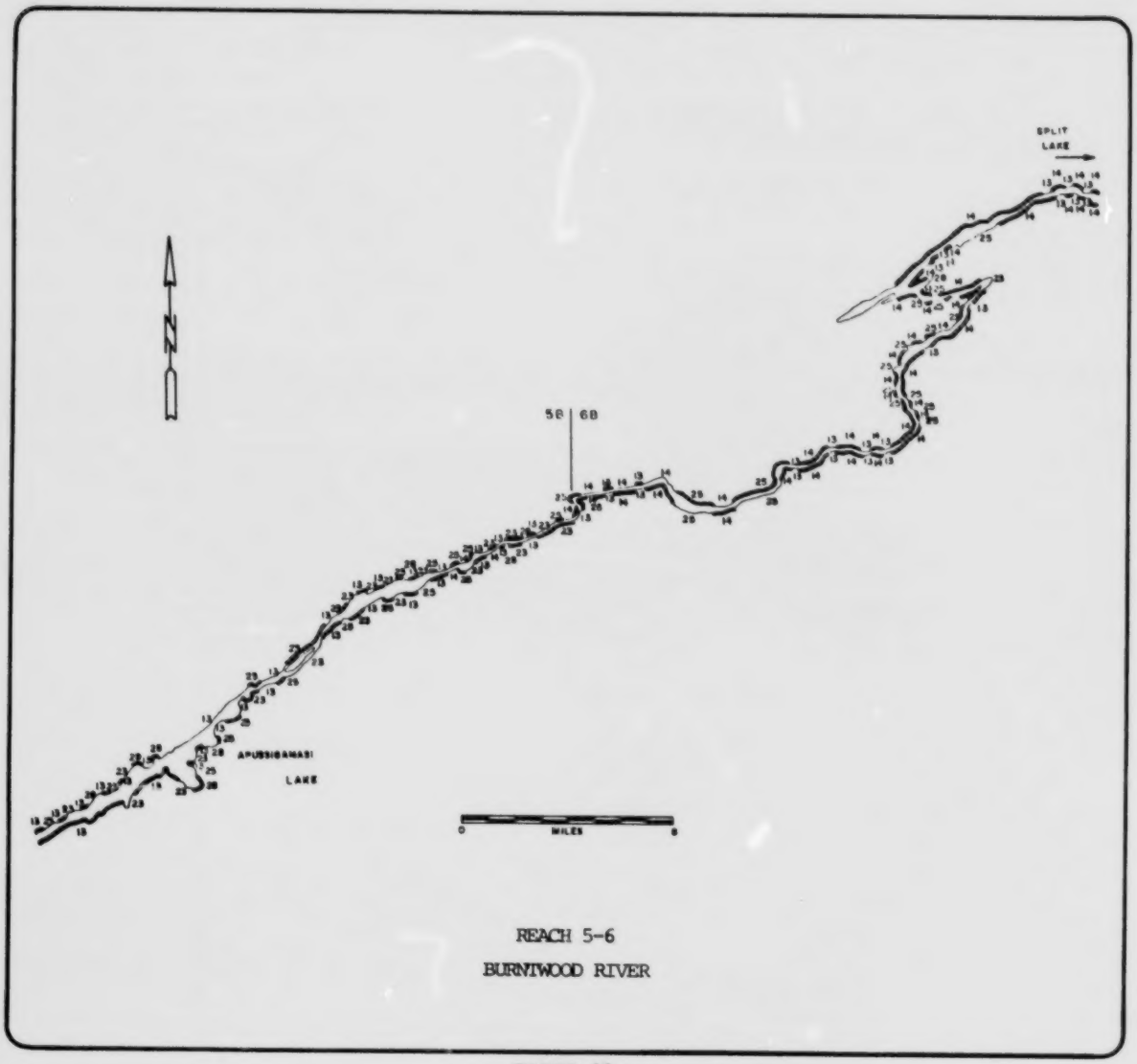
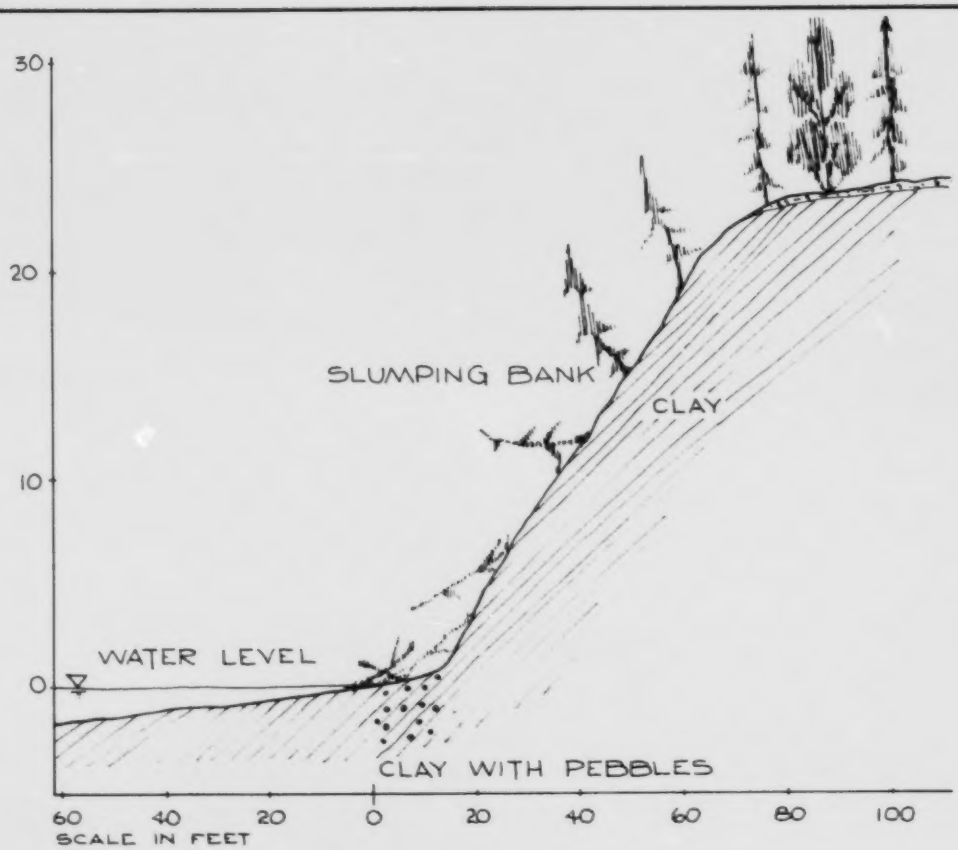

N
3B
5B
4B
3B
4B
1B
1B
4B
BIRCH TREE LAKE
1B
2B
WUSKWATIN LAKE
2B
1B
OPEGANO LAKE
1B
4B
0
MILES
REACH 1-5
BURNTWOOD RIVER

FIGURE 89



REACH 5-6
BURNTWOOD RIVER

FIGURE 90



PROFILE WEST SHORE OF OPEGANO LAKE

FIGURE 91

TABLE 11

RAT-BURNTWOOD RIVERS BELOW NOTIGI CONTROL

Reach	Shoreline Types														TOTALS
	11	12	13	14	15	21	22	23	24	25	26	27	28	31	
2R (partial)			2	13				6					1		22
3R (partial)			41	19				3					3		66
1B	2		15	26				19					9		71
2B			39	11			6	26					1		83
3B			2	2				20							24
4B			3	2				3		17			2		27
5B			28	2				24		5			4		63
6B			7	44				2		16			1		70
TOTALS	2		137	119			6	103		38			21		426

Note: All distances in miles.

TABLE 12

RAT-BURNTWOOD RIVERS BELOW NOTIGI CONTROL
SHORELINE TYPES BY REGIONS

Notigi to Wuskwatim Reach

Region	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS	Reaches Covered
Wapisu Lake			41	19				3					3		66	partial 3R
Rat R. Channel-Notigi to Three Point L.			2	13				6					1		22	partial 2R
Threepoint L.			22	3			6	19					1		51	2B
Wuskwatim L.			17	8				7					0.3		32	2B
Threepoint L. to Wuskwatim L.			>8	9				12					9		38	partial 1B
Wuskwatim L. to Taskinigup Falls			>2												2	partial 1B
TOTALS			92	52			6	47					14		211	

Note: All distances in miles

TABLE 13

RAT-BURNTWOOD RIVERS BELOW NOTIGI CONTROL
SHORELINE TYPES BY REGIONS

Wuskwatim to Manasan Reach

Region	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS	Reaches Covered
Taskinigup Falls to Opegano L.	>2		3	6				5							16	partial 1B
Opegano L.			2					2		4			1		9	partial 4B
Opegano L. to 5 miles above Birch Tree L.		>	2	11				2							15	partial 1B
Birch Tree L. and 5 miles above			1	2				1		13			1		18	partial 4B
Birch Tree L. to Manasan Falls	>			1				2							3	partial 3B
TOTALS	2		8	20				12		17			2		61	

Note: All distances in miles.

TABLE 14

RAT-BURNTWOOD RIVERS BELOW NOTIGI CONTROL
SHORELINE TYPES BY REGIONS

Manasan to First Rapids Reach

Region	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS	Reaches Covered
Manasan Falls to Mystery L.	>		2	1				18							21	partial 3B
Mystery L. to below Apussiganasi L.			28	2				24		5			4		63	5B
Below Apussiganasi L. to First Rapids	>		4	19						10					33	partial 6B
TOTALS			34	22				42		15			4		117	

Note: All distances in miles.

TABLE 15

RAT-BURNTWOOD RIVERS BELOW NOTIGI CONTROL
SHORELINE TYPES BY REGIONS

First Rapids to Split Lake Reach

Region	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS	Reaches Covered
First Rapids to Split L.			3	25				2		6			1		37	partial 6B

Note: All distances in miles

6.3.1.2 Natural State Conditions - Footprint Lake: Footprint Lake, a portion of the Burntwood drainage system, flows directly into Threepoint Lake via Footprint River (Figure 92). Footprint Lake in turn is fed by "The Lake With No Name" to the due north. Access to the community of Nelson House on Footprint Lake is via provincial road 391.

The area in general is characterized a thick lacustrine clay overburden resulting in a gently undulating to rolling topography. Overburden depths vary throughout the lake from steep banks (Photograph 92) to low banks (Photograph 93). In both cases, the banks were observed to be unstable. Due to past fire disturbances a variety of tree species ranging from Picea glauca (white spruce), Pinus banksiana (jack pine), Populus tremuloides (trembling aspen), Populus balsamifera (balsam poplar) and Betula papyrifera (white birch) can be found growing on well drained sites. Picea mariana (black spruce) is the dominant tree through this northern or coniferous forest area. Black spruce is particularly evident in areas of impeded drainage. Such sites are characterized by the thick organic deposits and sedge communities.

Natural State of Existing Shorelines: The shorelines of the area are as shown in Figure 92 and listed in Table 16. The shoreline distances of Footprint Lake and the Footprint River to P.R. 391 are shown apart from the shorelines north of P.R. 391.

In general, Footprint Lake is characterized by an alternating series of Type 13B, 11 and 15 shorelines, represented by some 19, 15 and 3 miles respectively. The 11 miles of bedrock control embayments (Type 14) are spread throughout the lake. Many of these are characterized by sandy beaches (Photograph 94). Other low lying embayments are either Type 24 or 28. The four miles of Type 28 are confined to the lake (Photograph 95) while the majority of the six miles of Type 24 are located on the Footprint River. The remaining two miles of shoreline (Type 23) are confined to Footprint River. Type 26 and 31 each represent less than one mile of shoreline each.

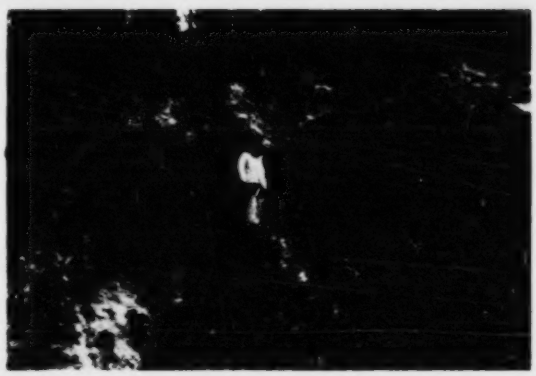
Exposed shorelines that have not achieved stability are still eroding (Photograph 96) while the protected shorelines have stabilized (Photograph 97).

The Footprint River north of P.R. 391 is primarily Type 23 while the lakeshore consists of an alternating series of Type 11, 13, and 15 shorelines represented by 21, 10 and 11 miles respectively. Embayments are either Type 14 (5 miles) or Type 28 (3 miles). The lake area can be distinguished from the Footprint Lake area by the higher occurrence of Type 11 shoreline and reduction in Type 24 shoreline (1 mile). Once more Types 26 and 31 each represent less than one mile of shoreline.

Inundated Terrain: The 810-foot contour as shown in Figure 92 is incomplete over some of the area due to the inadequate contour information used at the time of mapping.

Inundated terrain as described under the "Classification System for Inundated Terrain" Section 5.2.3 is primarily evident in the backshore areas of the lake embayments and river channels. Sedge communities are typical of the low wet saturated areas while treed muskeg is of a limited extent lying between the sedge communities and clay

overburden sites. In general, the tributary streams of the Footprint River and adjoining lakes are characterized by sedge communities flanked by treed muskeg. The extent of treed muskeg is primarily a function of the slope. Well drained areas will be characterized as clay overburden areas.



PHOTOGRAPH 92 - Deep slumping varved clay bank on Footprint Lake near Nelson House. This deep clay overburden is actively eroding. The site may have been disturbed by machinery.

PHOTOGRAPH 93 - Shallow, eroding clay bank on Footprint Lake near Nelson House. The low clay land is still eroding as indicated by the erosion scarp.

PHOTOGRAPH 94 - Footprint Lake. Sandy embayment on a type 14 shoreline.

PHOTOGRAPH 95 - Footprint Lake. Low Willow Shoreline (Type 28) with extensive offshore marsh.

PHOTOGRAPH 96 - Nelson House area, a eroding ing clay shoreline (Type 23).

PHOTOGRAPH 97 - Nelson House area, a stable clay shoreline of moderate height and mild slope. A narrow marsh zone has become established.

TABLE 16

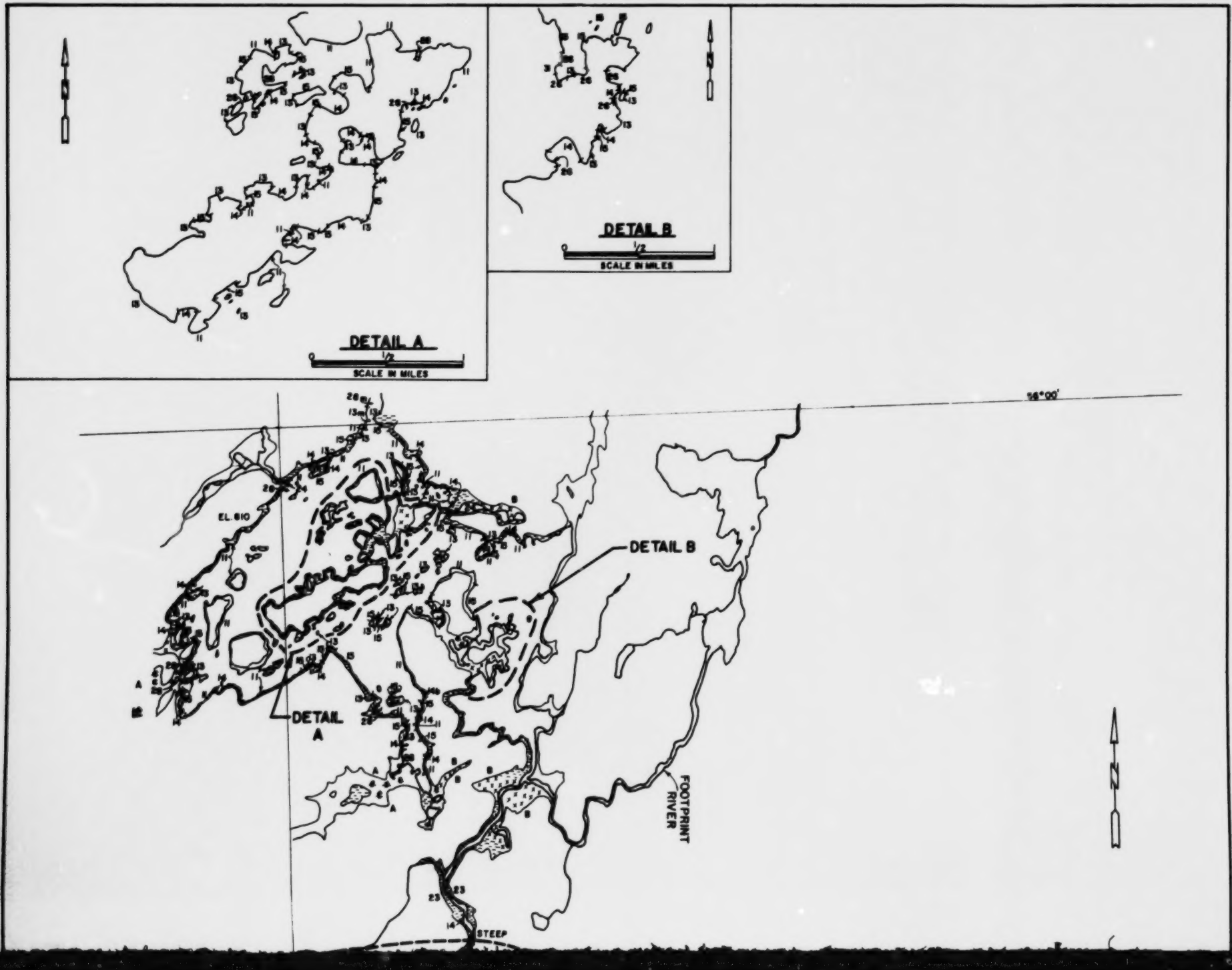
NELSON HOUSE

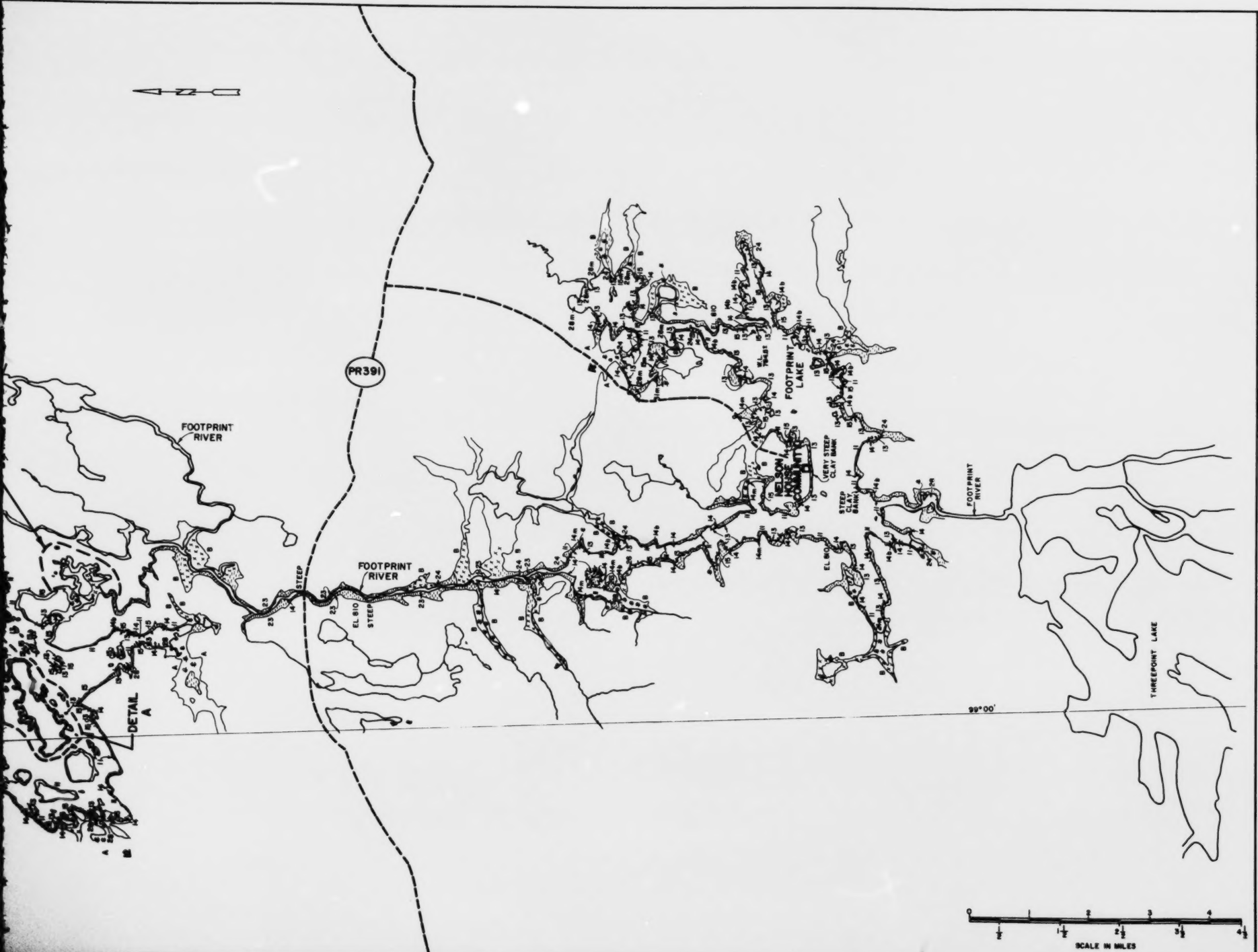
MILEAGE OF SHORELINE TYPES

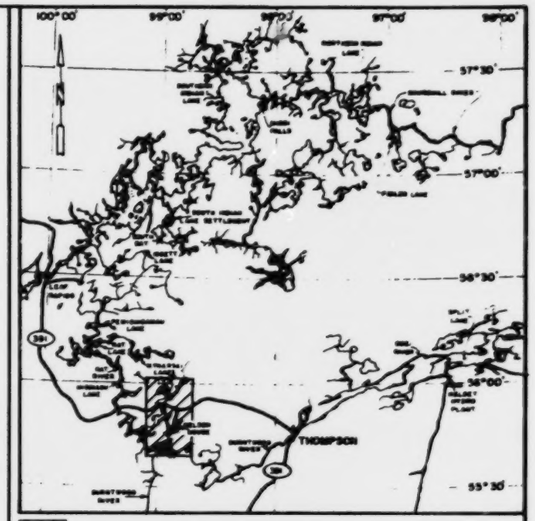
Class	11	11a	12	13	13a	14	14b	14c	14ba	15	15b	15c	15ba	21	22	22a	23	23a	24	24b	24c	25	26	26a	26c	27	27a	28	28a	31	31a	TOTAL
Lower	14.5			18.6		7.3	1.5	2.0		2.9		0.2					2.2		3.9		0.7		0.5					1.2	2.3		0.4	58.2
Upper	20.5			9.3	0.2	4.7				10.7							4.2		1.0				0.4					2.8	0.6	0.1		54.5
TOTAL	35.0			27.9	0.2	12.0	1.5	2.0		13.6		0.2					6.4		4.9		0.7		0.9					4.0	2.9	0.1	0.4	112.7

NOTE: The term "Lower" refers to the portion of Footprint Lake and the Footprint River below Provincial Road 391.

"Upper" refers to the portion above Provincial Road 391. All distances are in miles.


DETAIL A
SCALE IN MILES
DETAIL B
SCALE IN MILES
EL. 610
DETAIL B
DETAIL A
FOOTPRINT RIVER
STEEP





LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 92

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

NELSON HOUSE AREA

SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
D.S.	M.S.	T.M.	DATE	DATE

SCALE	DATE	DRAWING NO.	FILE NO.
AS SHOWN	APRIL/74	12 - 58	61-1-1025

6.3.2 WATER LEVELS AND FLOWS - NOTIGI TO SPLIT LAKE:

6.3.2.1 Water Levels and Flows - Notigi to Wuskwatim: Between Notigi and Wuskwatim sites, the Rat-Burntwood discharges are considerably altered by tributary inflow and local run-off. The Burntwood River at Threepoint Lake is the greatest single input in this reach and contributes approximately 70 percent of the local inflow between Notigi and Wuskwatim. Burntwood River flows are essentially constant between Threepoint Lake and Wuskwatim, and can, therefore, be considered equal to discharges at Wuskwatim.

The flows in the Rat River at Notigi have been discussed in section 6.2.2, and will not be discussed further here.

Natural and regulated discharges in the Burntwood River at Wuskwatim are shown in Table 17.

Under diversion, peak discharges at Wuskwatim will occur during mid-summer (June, July and August) and will be about 34,000 cfs. Lower discharges will occur during the fall and early winter with lowest flows in late winter. Minimum flow (at 5% probability) will be near 18,300 cfs. Discharges less than this may occur, but this is a remote possibility. The expected minimum monthly discharge has been taken as 18,300 cfs.

The discharge parameters for the Burntwood River from Threepoint Lake to Wuskwatim are outlined in the following Table:

TABLE 17

BURNTWOOD RIVER DISCHARGES AT WUSKWATIM

	Natural	Regulated	Change
Minimum	200 cfs (Mar)	18,300 cfs (Apr)	+18,100 cfs
Mean	3,100 cfs	31,200 cfs	+28,100 cfs
Median	2,000 cfs	32,800 cfs	+30,800 cfs
Maximum	15,000 cfs (June)	34,000 cfs	+18,500 cfs
Long-term range	14,800	15,700 cfs	+ 900 cfs
Maximum monthly fluctuation:			
rise	≤20,000 cfs (June)	≤20,000 cfs (Mar to May)	
drop	≤10,000 cfs (June, July, Aug, Oct)	≤20,000 cfs (Feb to May)	
Open water mean discharge	5,000 cfs	33,400 cfs	
Winter mean discharge	1,200 cfs	29,000 cfs	

Water surface profiles for this reach are presented in Figure 93 (no hydro development at the Wuskwatim site) Figure 94 (Wuskwatim forebay at 800) and Figure 95 (Wuskwatim forebay at 810). These profiles are drawn for the following conditions:

1. Normal natural flow. The natural mean flow is 3,100 cfs at Wuskwatim, and the summer mean is 5,000 cfs. The natural profile is given approximately by the 5,000 cfs profile.
2. Normal regulated flow (open water) for a mean discharge of 33,400 cfs at Wuskwatim.
3. Normal ice cover, at the maximum winter discharge of 33,200 cfs.
4. Extreme ice jam conditions with a maximum winter discharge of 33,200 cfs.

The water levels in this reach may be represented by the levels of Wapisu, Threepoint and Wuskwatim Lakes as shown in the following Tables:

TABLE 18

WATER LEVELS IN BURNTWOOD RIVER

AT WAPISU LAKE

Flow Condition	Development at Wuskwatim		
	None	Forebay at 800	Forebay at 810
Natural, open water Q = 5,000 cfs	786.5	800	810.0
Diversion, open water Q = 33,400 cfs	802.0	805	812.0
Diversion, normal ice Q = 33,200 cfs	813.0	813	813.5
Diversion, extreme ice jam Q = 33,200 cfs	820.0	820	N.A.

TABLE 19

WATER LEVELS IN BURNTWOOD RIVER AT THREEPOINT LAKE

(Also at Footprint Lake)

Flow Condition	Development at Wuskwatim		
	None	Forebay at 800	Forebay at 810
Natural, open water Q = 5,000 cfs	784.5	800	810.0
Diversion, open water Q = 33, 400 cfs	800.0	804	812.0
Diversion, normal ice Q = 33,200 cfs	812.0	812	812.5
Diversion, extreme ice jam Q = 33,200 cfs	820.0	820	N.A.

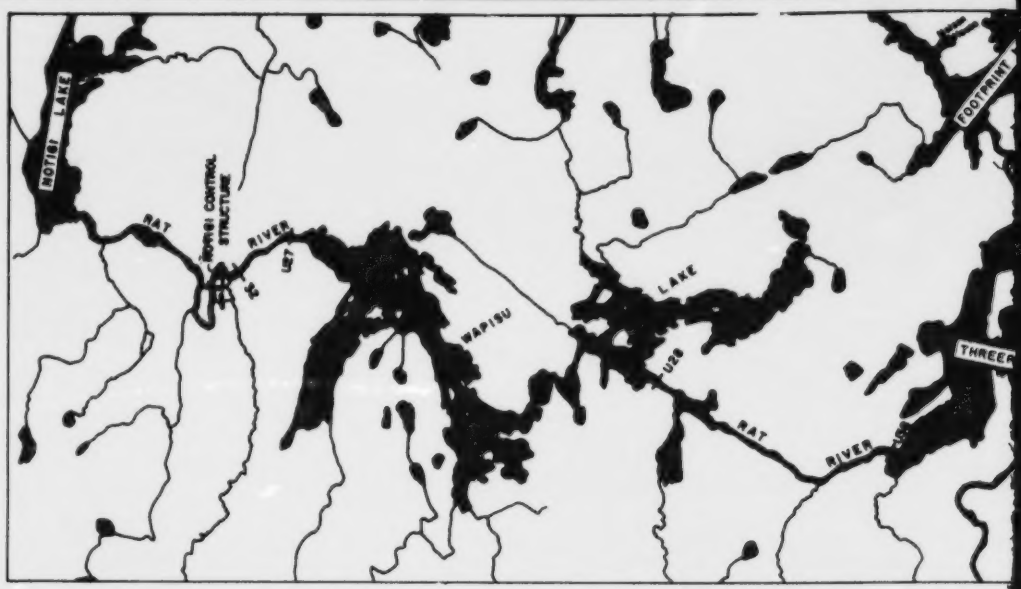
TABLE 20

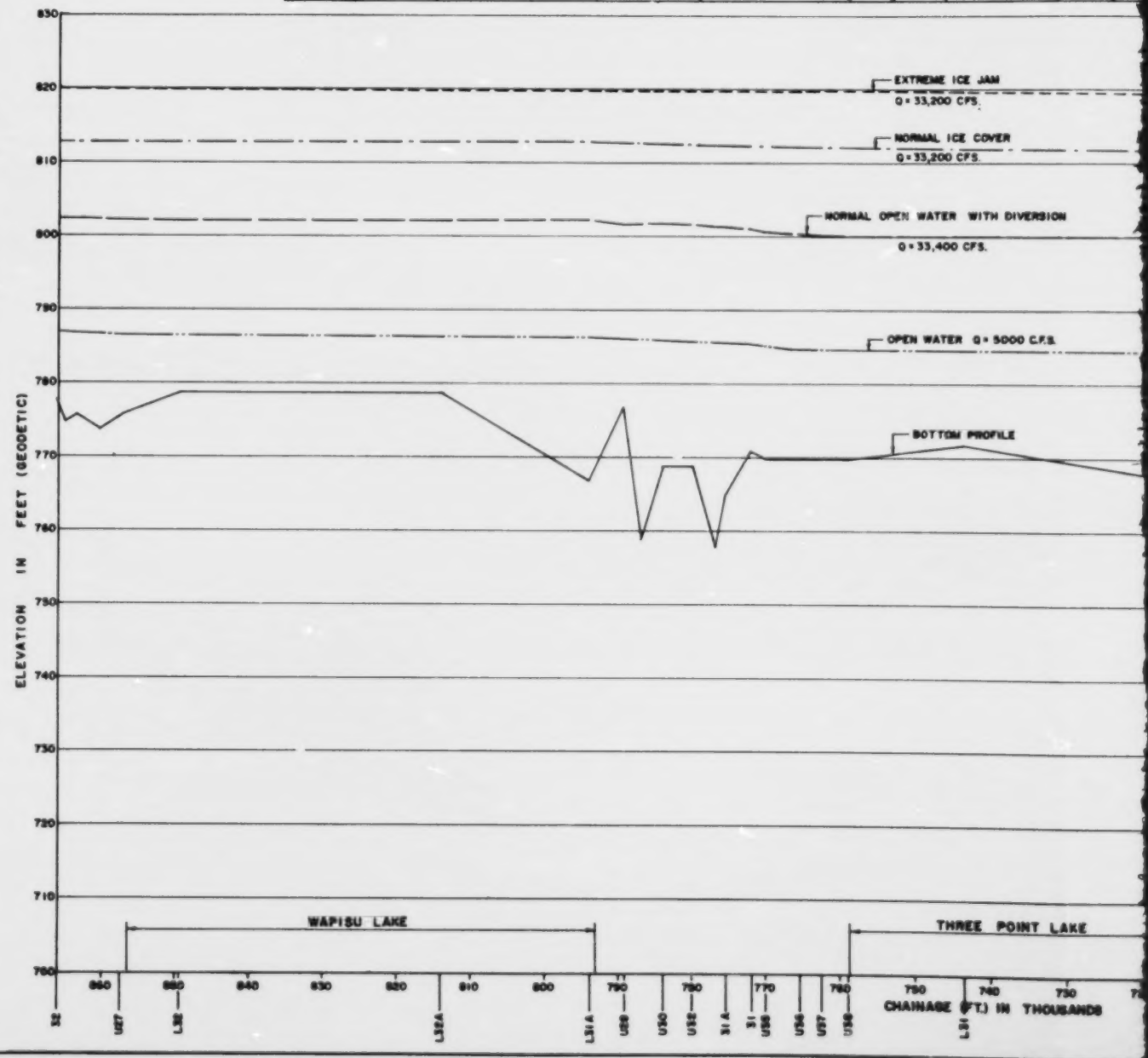
WATER LEVELS IN BURNTWOOD RIVER

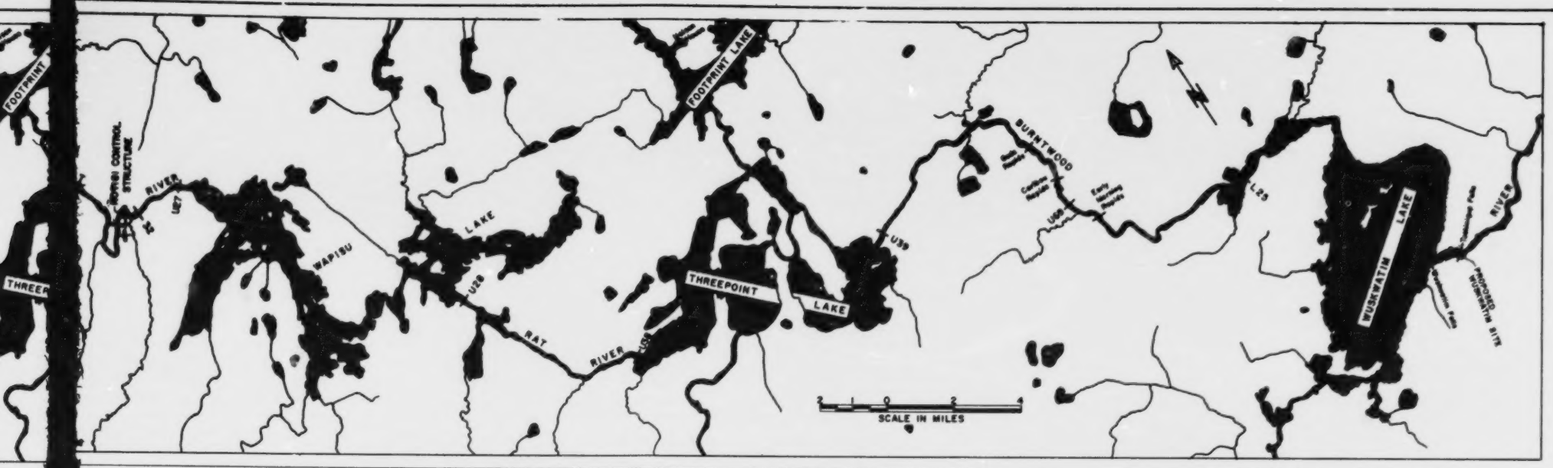
AT WUSKWATIM LAKE

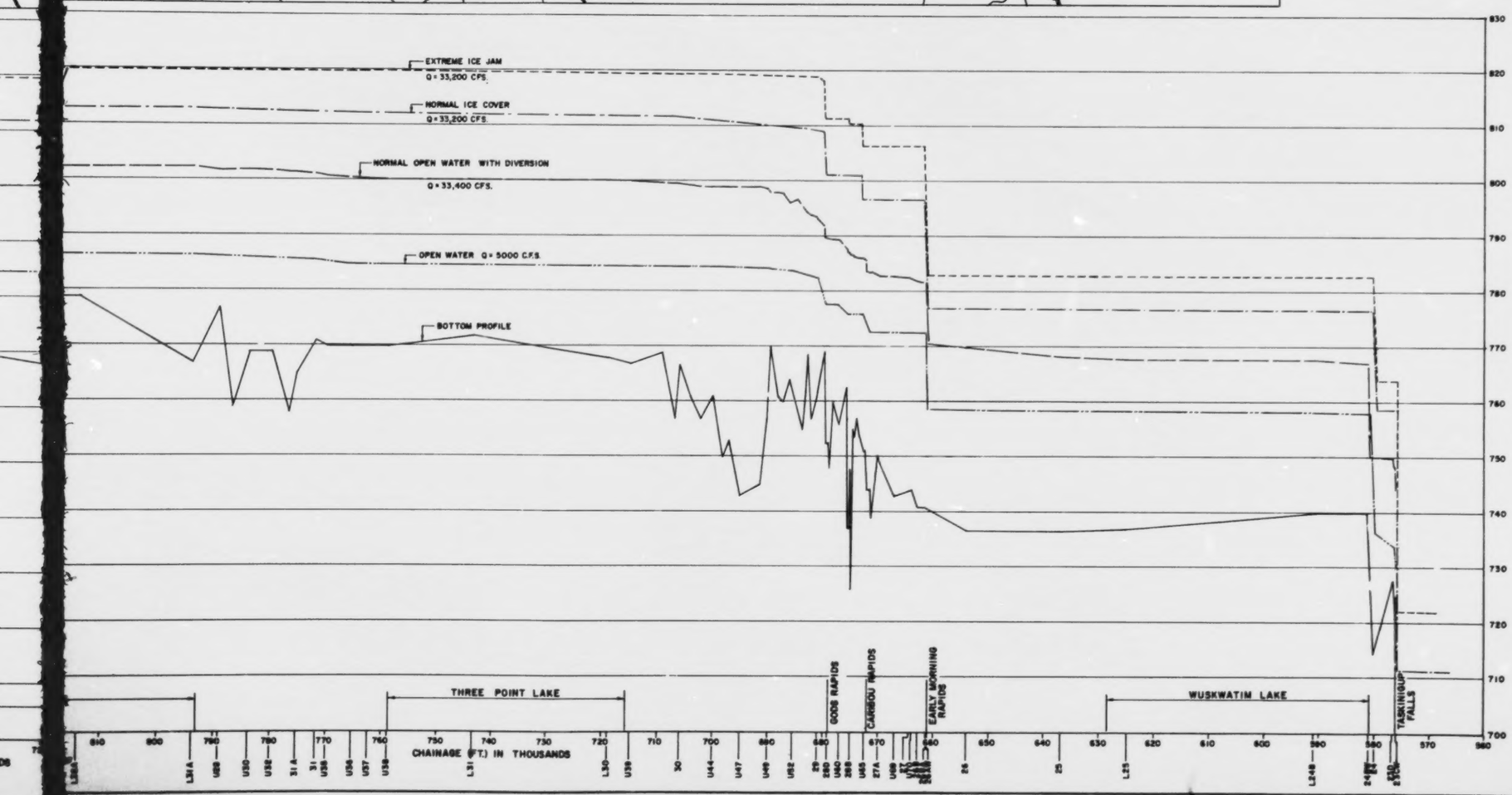
Flow Condition	Development at Wuskwatim		
	None	Forebay at 800	Forebay at 810
Natural, open water Q = 5,000 cfs	758	800	810
Diversion, open water Q = 33,400 cfs	768	800	810
Diversion, normal ice Q = 33,200 cfs	777	800	810
Diversion, extreme ice jam Q = 33,200 cfs	783	800	810

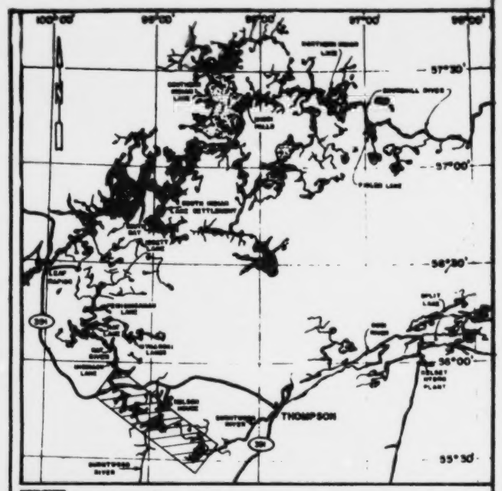
It is probable that the water level rise associated with the change from "Diversion - open water" to "Diversion - normal ice" would occur during a period of six weeks in the early winter and the corresponding drop in the spring may take place over a period of three weeks. The extreme ice jam condition would be a rare event.


NOTIGI LAKE
NOTIGI CONTROL STRUCTURE
RAT RIVER
U27
WAPISU LAKE
U28
RAT RIVER
FOOTPRINT
THREE


EXTREME ICE JAM
Q = 33,200 CFS.
NORMAL ICE COVER
Q = 33,200 CFS.
NORMAL OPEN WATER WITH DIVERSION
Q = 33,400 CFS.
OPEN WATER Q = 5000 C.F.S.
BOTTOM PROFILE
ELEVATION IN FEET (GEODETIC)
830
820
810
800
790
780
770
760
750
740
730
720
710
700
WAPISU LAKE
THREE POINT LAKE
860
850
840
830
820
810
800
790
780
770
760
750
740
730
CHAINAGE (FT.) IN THOUSANDS
32
U27
L38
L32A
L31A
U29
U30
U32
31A
31
U33
U34
U37
U38
L31
L30A







LOCATION PLAN

SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 33,400 CFS. BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 33,200 CFS.
4. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
5. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55

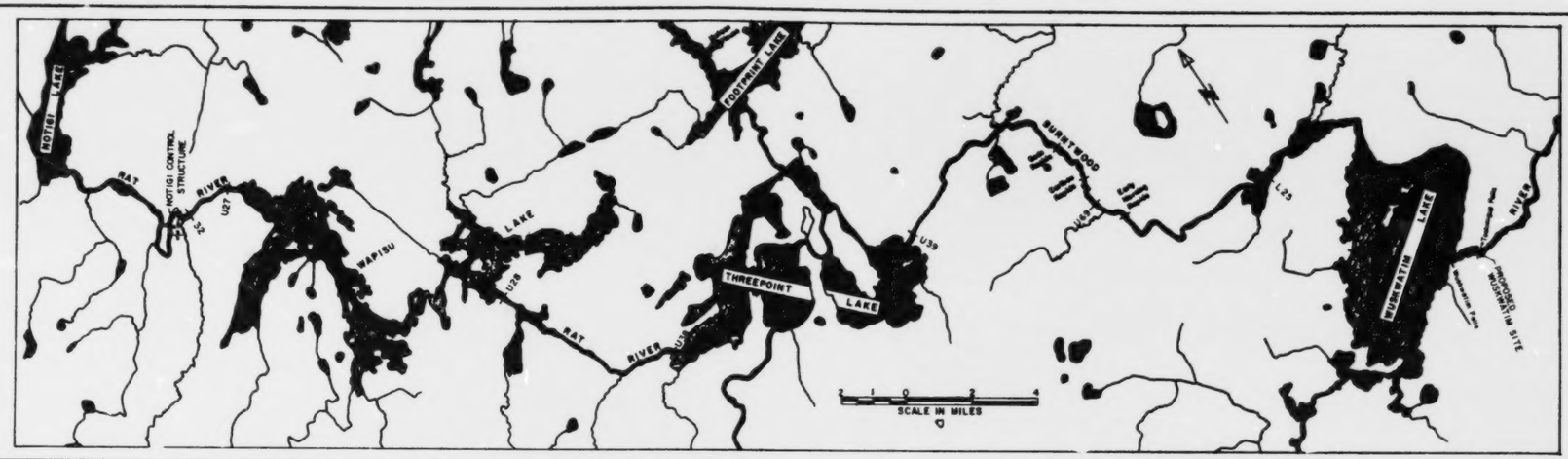
FIG. 93

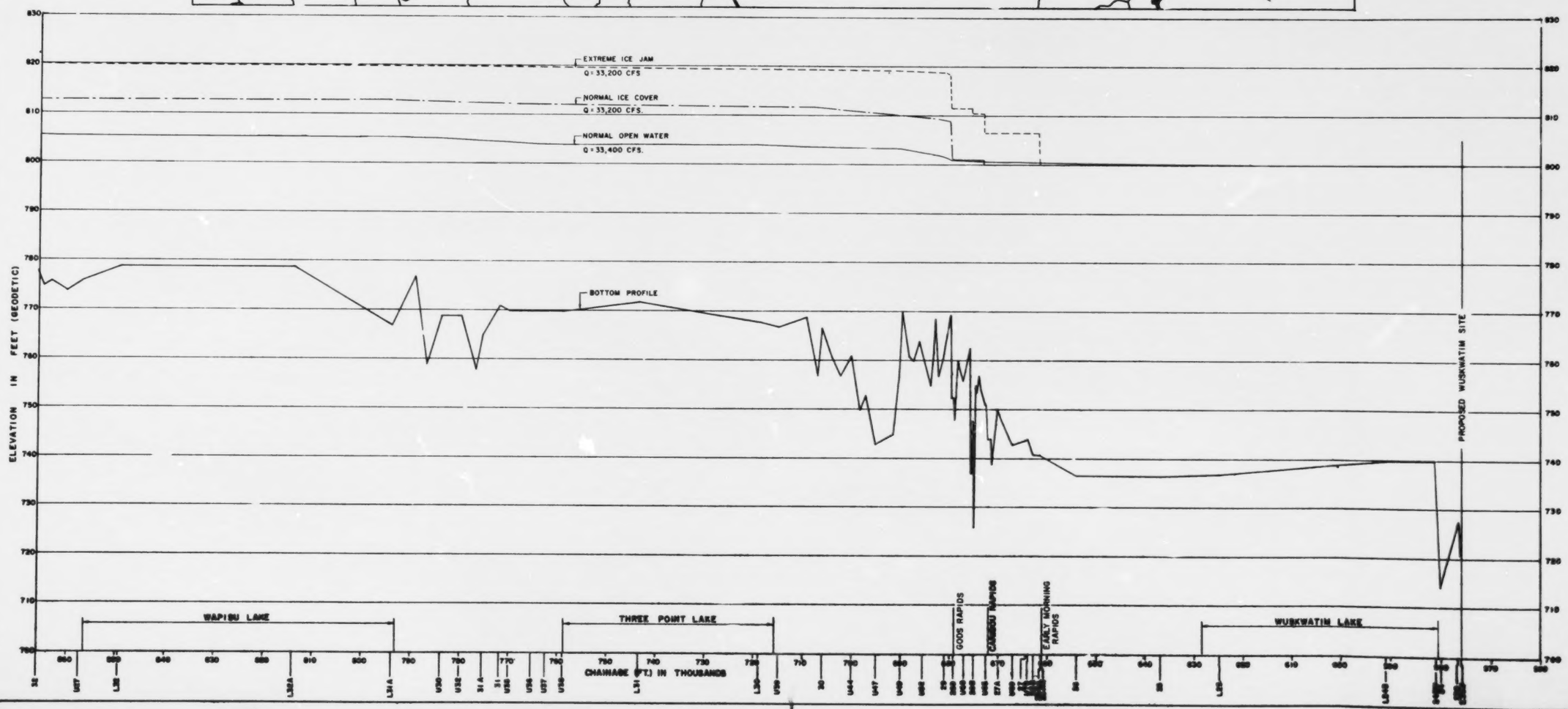
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

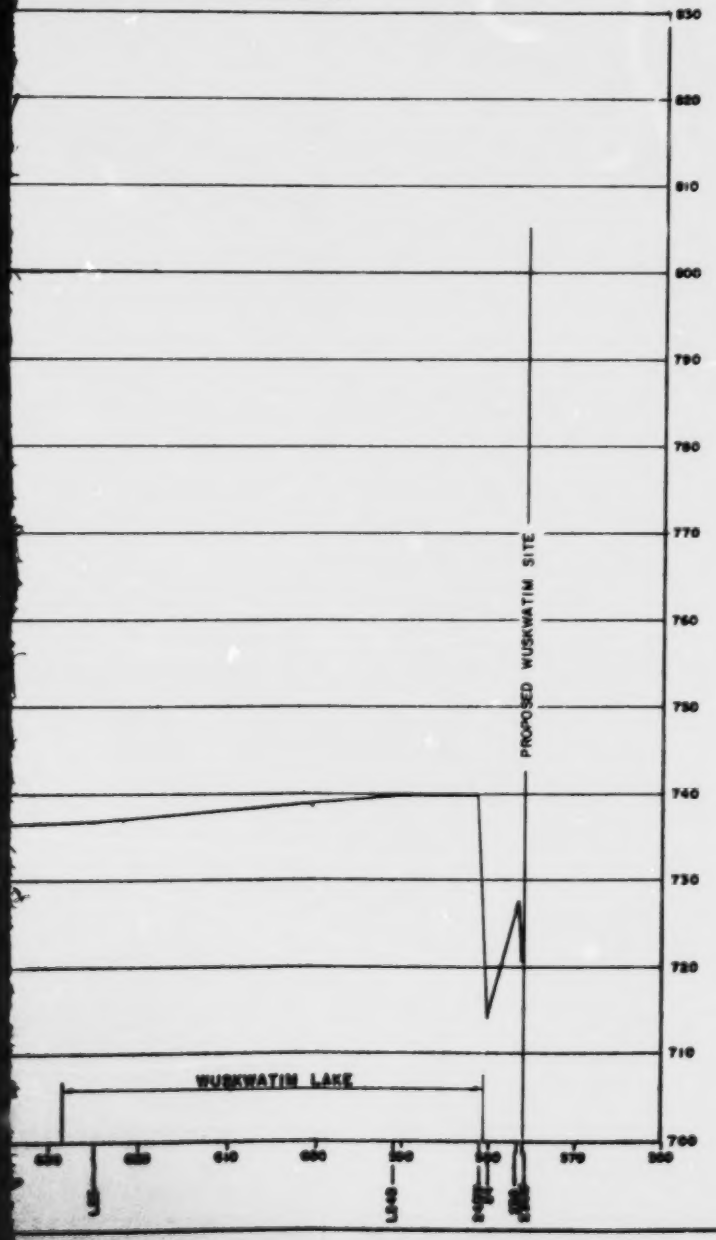
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

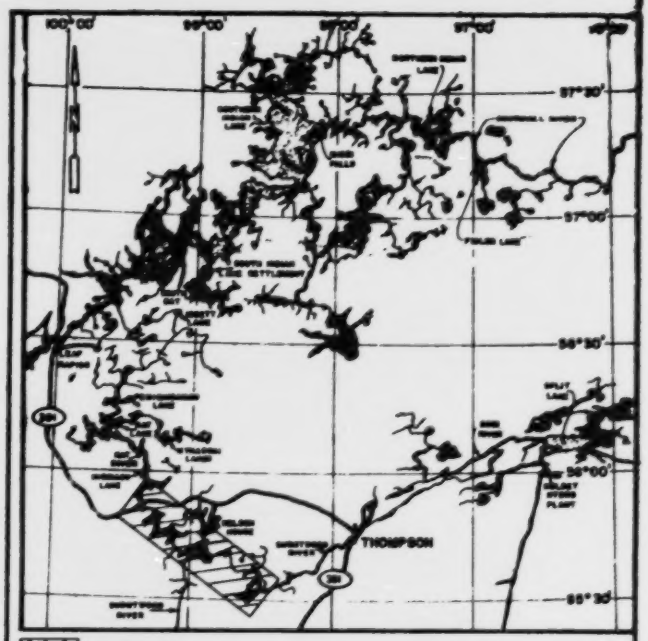
PHYSICAL IMPACT STUDY
RAT-BURNTWOOD RIVER PROFILES
NOTIGI TO WUSKWATIM REACH
WITH NO WUSKWATIM DEVELOPMENT

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
L.S.	V.K.	L.S.	DATE	
SCALE: AS SHOWN	DATE: FEB., 1976	SHEET NO. 13 OF 58	FILE NO. 61-1-1025	


MOTEY LAKE
RAT
MOTIGI CONTROL STRUCTURE
RIVER
U27
L26
WAPISU
LAKE
U28
RAT
RIVER
U29
FOOTPRINT LAKE
THREEPOINT
LAKE
U39
BURNTWOOD
U43
L29
WUSKWATIM
LAKE
RIVER
PROPOSED WUSKWATIM SITE
SCALE IN MILES


EXTREME ICE JAM
Q = 33,200 CFS
NORMAL ICE COVER
Q = 33,200 CFS.
NORMAL OPEN WATER
Q = 33,400 CFS.
BOTTOM PROFILE
ELEVATION IN FEET (GEODETIC)
CHAINAGE (FT.) IN THOUSANDS
WAPISU LAKE
THREE POINT LAKE
GODS RAPIDS
CARIBOU RAPIDS
EARLY MORNING RAPIDS
WUSKWATIM LAKE
PROPOSED WUSKWATIM SITE





= LOCATION OF MAP

LOCATION PLAN

SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 33,400 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 33,200 CFS.
4. PROPOSED WUSKWATIM FOREBAY IS ASSUMED AT ELEVATION 800.0.
5. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
6. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55.

FIG. 94

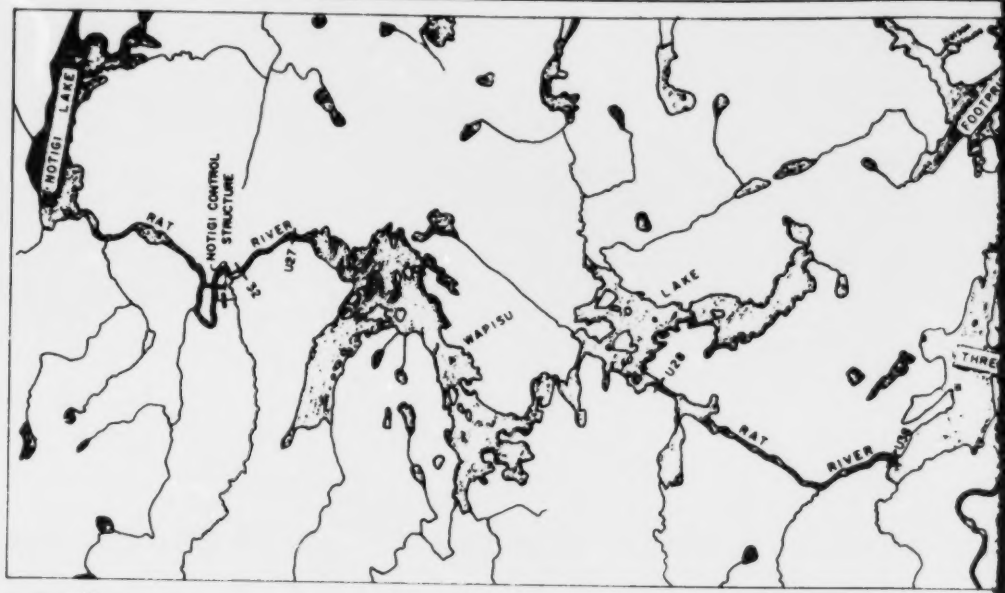
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

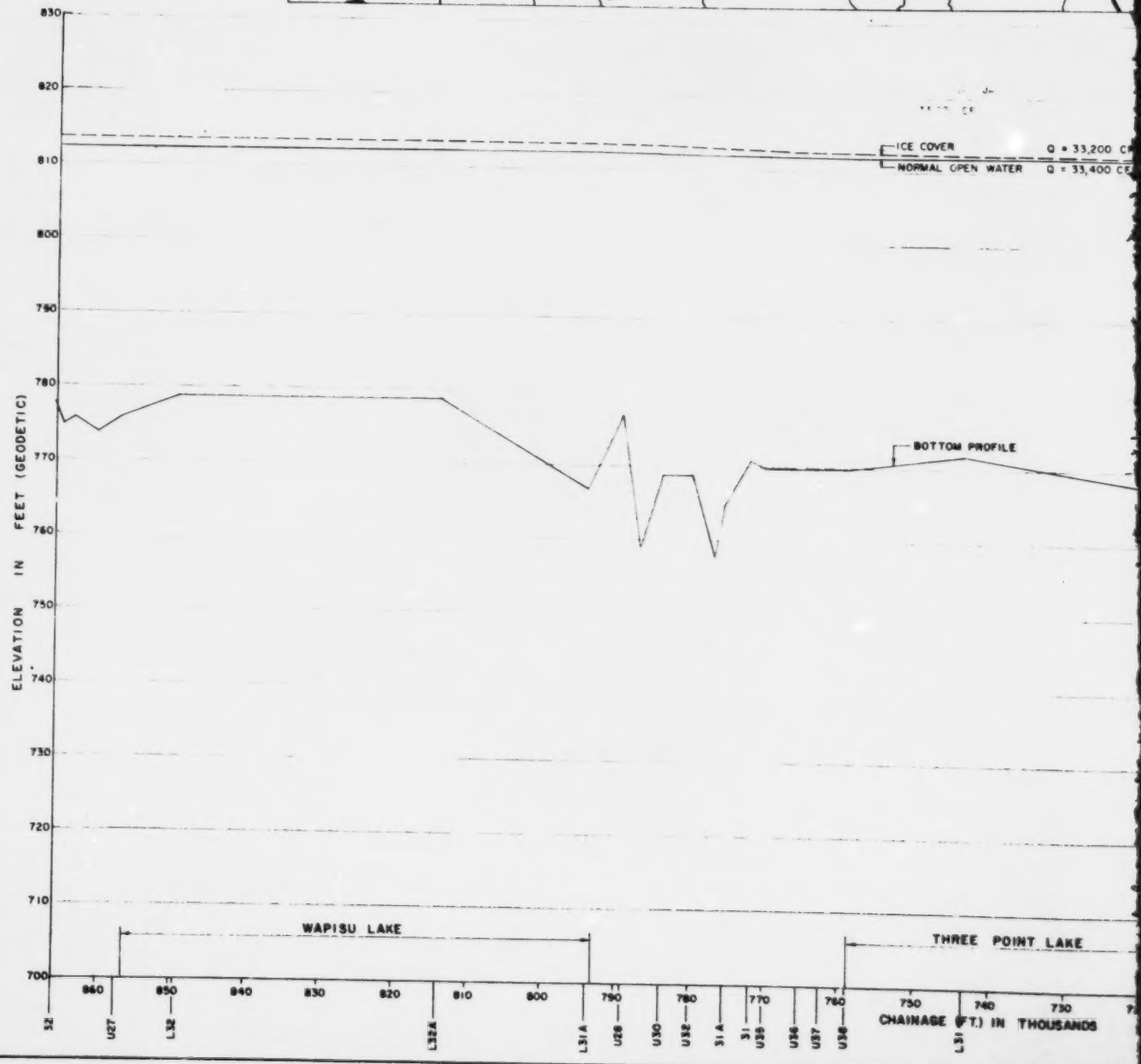
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

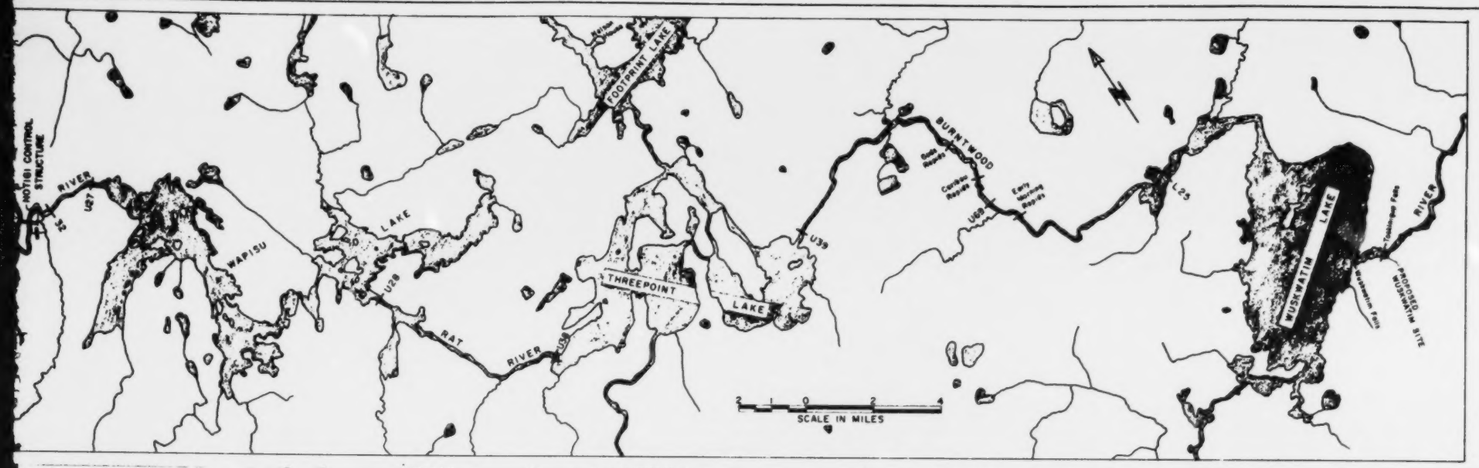
PHYSICAL IMPACT STUDY
RAT-BURNTWOOD RIVER PROFILES
NOTIGI TO WUSKWATIM REACH
WITH WUSKWATIM FOREBAY AT ELEVATION 800

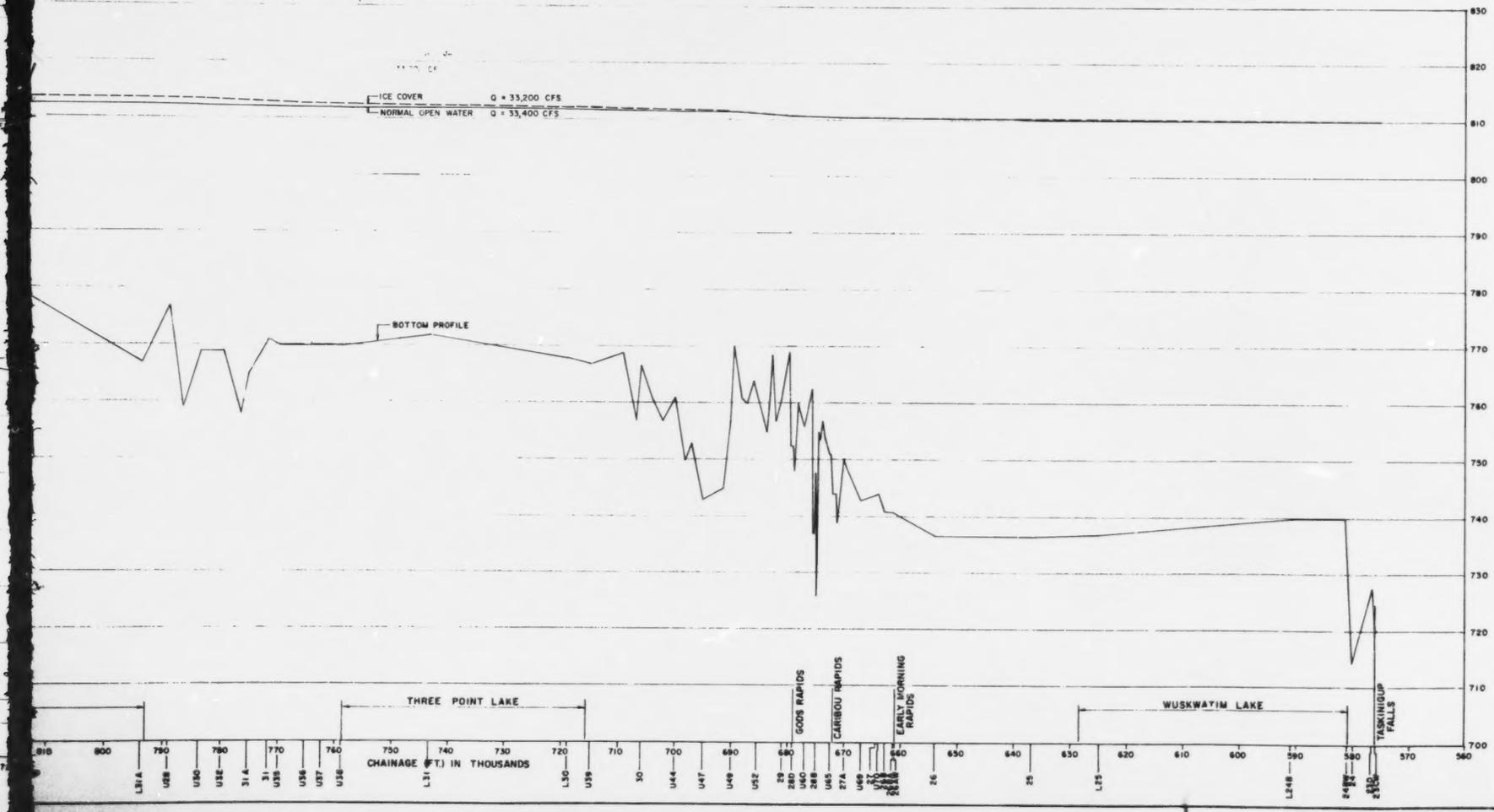
PREPARED	DESIGN	CHECKED	SUBMITTED	APPROVED
L. B.	V. K.	L. B.	DATE	DATE

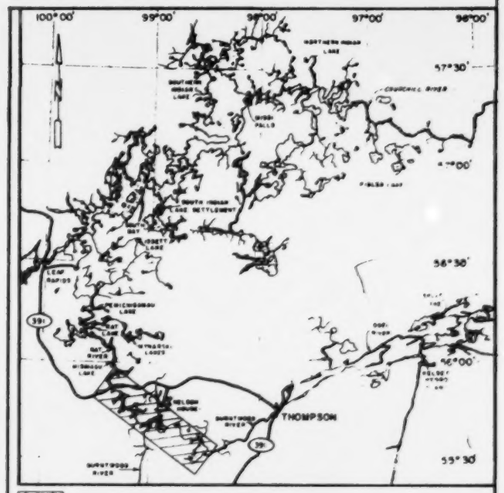
SCALE	DATE	DRAWING NO.	FILE NO.
AS SHOWN	FEB., 1974	14 OF 58	61-1-1025


NOTIGI LAKE
NOTIGI CONTROL STRUCTURE
RAT RIVER
U27
L32
WAPISU LAKE
U28
RAT RIVER


ICE COVER
NORMAL OPEN WATER
BOTTOM PROFILE
ELEVATION IN FEET (GEODETIC)
830
820
810
800
790
780
770
760
750
740
730
720
710
700
WAPISU LAKE
THREE POINT LAKE
860
850
840
830
820
810
800
790
780
770
760
750
740
730
U27
L32
L32A
L31A
U28
U30
U32
31A
31
U35
U36
U37
U38
L31
CHAINAGE (FT.) IN THOUSANDS







▨ = LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT - BURNTWOOD RIVER SYSTEM DECEMBER '73
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 33,400 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 33,200 CFS WITH WUSKWATIM FOREBAY AT ELEVATION 810, EXTREME ICE JAM LEVELS ARE NOT EXPECTED
4. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION
5. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55.

FIG. 95

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

RAT-BURNTWOOD RIVER PROFILES

NOTIGI TO WUSKWATIM REACH

WITH WUSKWATIM FOREBAY AT ELEVATION 810

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
L.S	V.K	L.S	DATE	DATE
SCALE: AS SHOWN	DATE: FEB., 1974	SHEET NO.: 15 OF 58	FILE NO.: 61-1-1028	

6.3.2.2 Water Levels and Flows Wuskwatim to Manasan: The Burntwood River tributary drainage area between the Wuskwatim and Manasan sites is approximately 6% of the total drainage area above Wuskwatim. Local run-off is therefore very small compared to Burntwood River flows at Wuskwatim, and discharges for this reach are changed very little from those at Wuskwatim (Figure 96).

This discussion of discharges at Wuskwatim (Section 6.3.2.1), therefore, applies to this reach as well.

The following Table summarizes the major discharge parameters at Manasan Falls.

TABLE 21

BURNTWOOD RIVER DISCHARGES AT MANASAN

	Natural	Regulated	Change
Minimum	210 cfs (Mar)	18,300 cfs (Apr)	+18,100 cfs
Mean	3,300 cfs	31,400 cfs	+28,100 cfs
Median	2,100 cfs	32,900 cfs	+30,800 cfs
Maximum	16,400 cfs (June)	34,900 cfs (June)	+18,500 cfs
Long-term range	16,200 cfs	16,600 cfs	+ 400 cfs
Maximum monthly fluctuation:			
rise	≤20,000 cfs (June)	≤20,000 cfs (Mar to June)	
drop	≤10,000 cfs June July, Aug, &Oct)	≤20,000 cfs (Feb (Feb to May)	
Open water mean discharge	5,300 cfs	33,700 cfs	
Winter mean discharge	1,300 cfs	29,100 cfs	

Water surface profiles for this reach are shown in Figure 97 (no hydro development at Manasan Falls) and Figure 98 (Manasan Summer Forebay at 690). These profiles are for the following conditions:

1. Normal natural flow. The natural mean monthly flow is 3,300 cfs at Manasan, and the summer mean is 5,300 cfs. The natural profile is, therefore, approximated by the 5,000 cfs profile shown.
2. Normal regulated flow (open water), at the mean open-water discharge of 33,700 cfs.
3. Normal ice cover at the maximum winter discharge of 34,000 cfs.
4. Extreme ice jam conditions at the maximum winter discharge of 34,000 cfs.

The water levels in this reach may be represented by the water levels in Opegano and Birchtree Lakes reported in the following Tables:

TABLE 22

WATER LEVELS IN BURNTWOOD RIVER

AT OPEGANO LAKE

Flow Condition	Development at Manasan	
	None	Forebay at 690
Natural Open Water Q = 5,000 cfs	678	690
Diversion, open water Q = 33,700 cfs	685	690
Diversion, normal ice Q = 34,000 cfs	694	694
Diversion, extreme ice jam Q = 34,000 cfs	702	702

TABLE 23

WATER LEVELS IN BURNTWOOD RIVER

AT BIRCHTREE LAKE

Flow Condition	Development at Manasan	
	None	Forebay at 690
Natural, open water Q = 5,000 cfs	628	690
Diversion, open water Q = 33,700 cfs	636.5	690
Diversion, normal ice Q = 34,000 cfs	644	690
Diversion, extreme ice jam Q = 34,000 cfs	652	690

It is probable that the water level rise from "Diversion - open water" to Diversion - normal ice" would occur during a period of possibly six weeks in early winter and the corresponding drop in the spring may take place over a period of three weeks. The extreme ice jam condition would be a rare event.

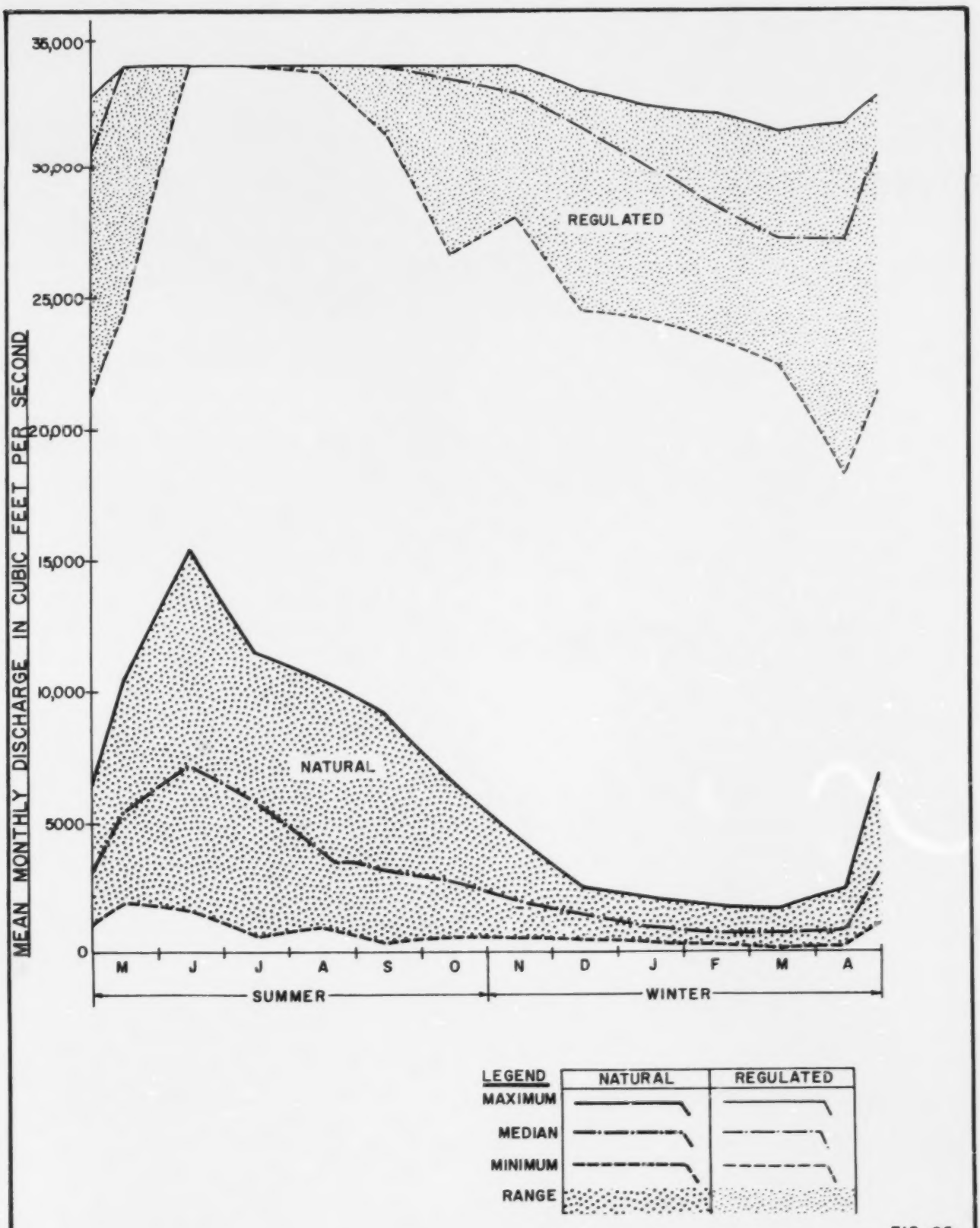


FIG. 96

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

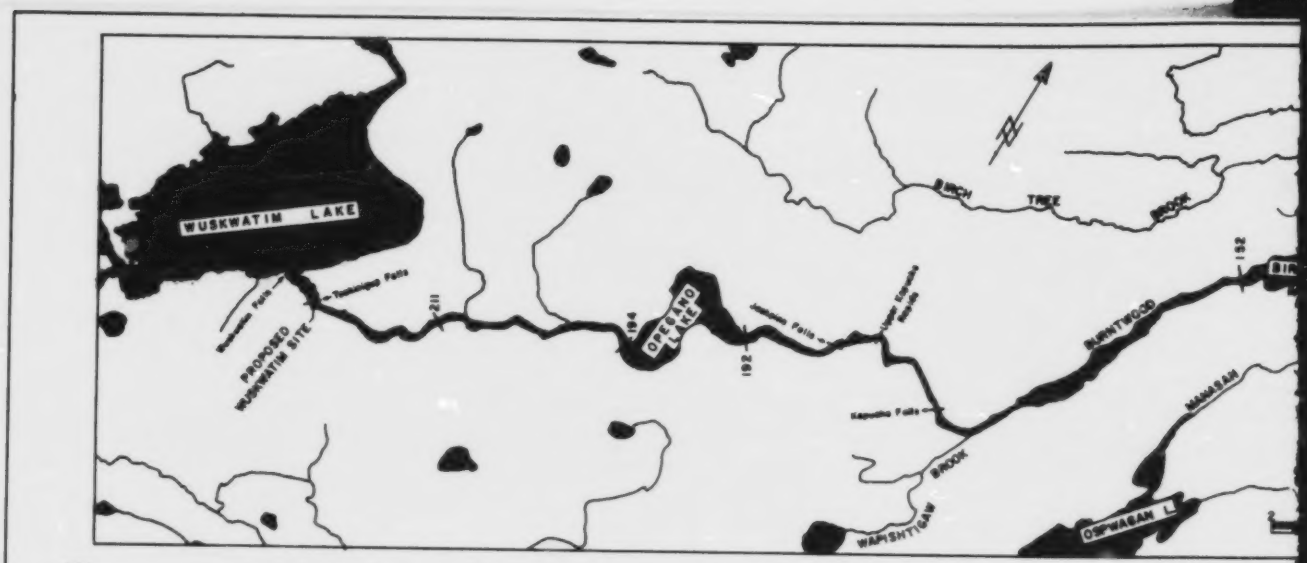
WATER RESOURCES BRANCH

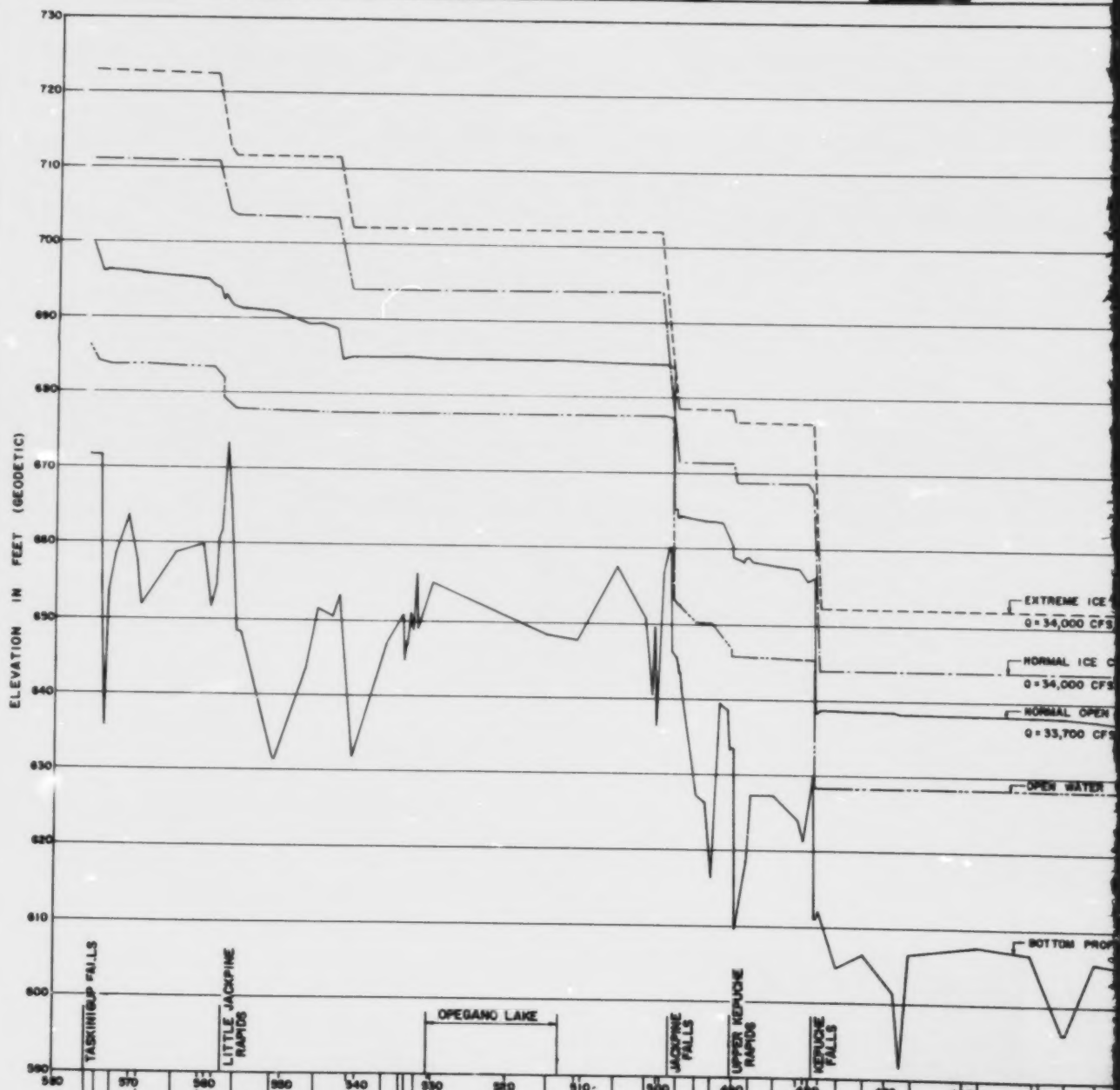
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

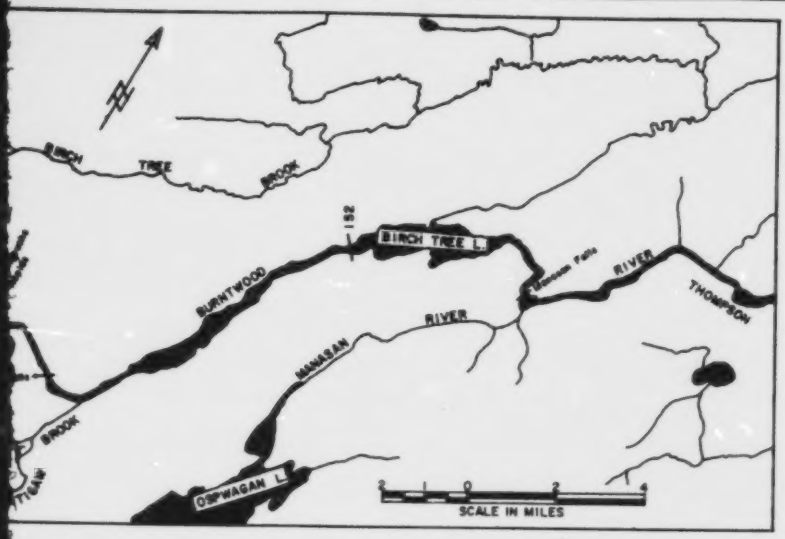
PHYSICAL IMPACT STUDY
DISCHARGES AT WUSKWATIM

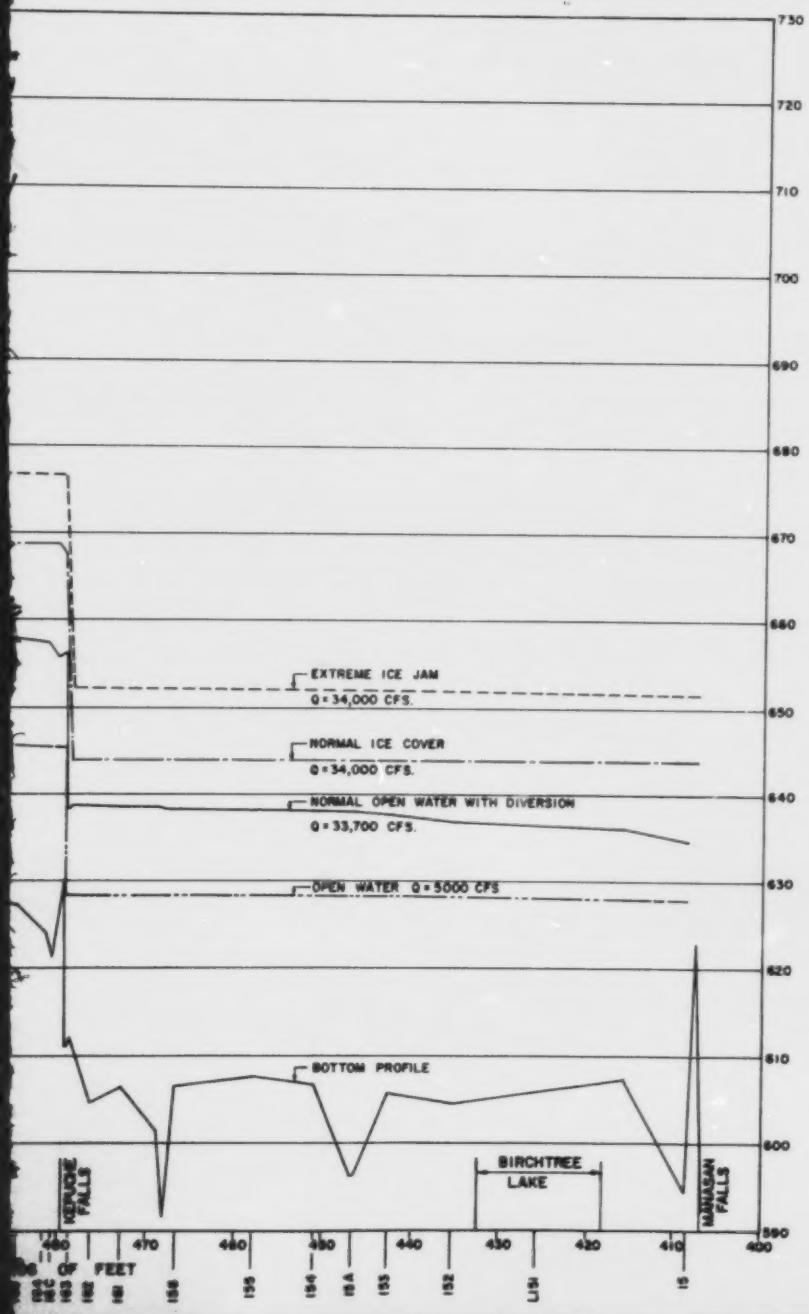
PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	CHECKED S.P. F.P.	DATE	DATE

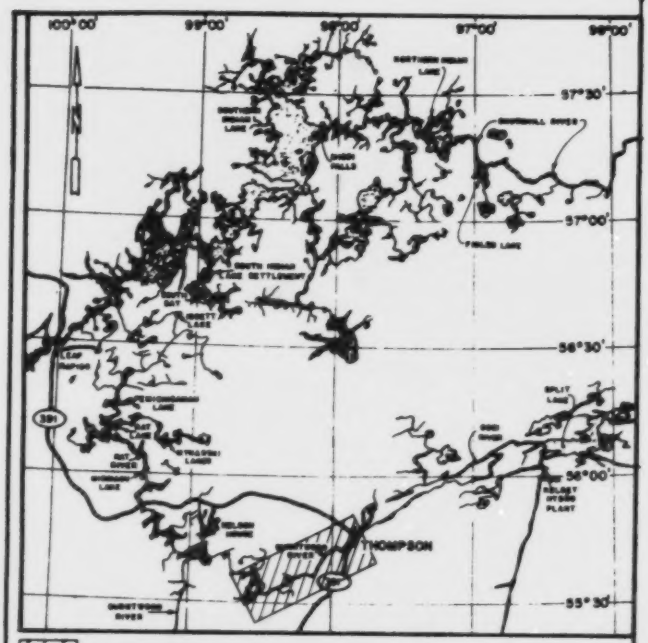
SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN / 74	16 OF 58	61 - 1 - 1025


WUSKWATIM LAKE
PROPOSED WUSKWATIM SITE
OPEGANO LAKE
BIRCH TREE BROOK
SUNTTWOOD
MANASAN
OPWABAN L
WAPISHTIGAW BROOK
192
194
211


ELEVATION IN FEET (GEODETIC)
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
EXTREME ICE
Q = 34,000 CFS
NORMAL ICE
Q = 34,000 CFS
NORMAL OPEN
Q = 33,700 CFS
OPEN WATER
BOTTOM PROF
TASKINIGUP FALLS
LITTLE JACKPINE RAPIDS
OPEGANO LAKE
JACKPINE FALLS
UPPER KEPUCHE RAPIDS
KEPUCHE FALLS
KEPUCHE FALLS
CHAINAGE IN THOUSANDS OF FEET







= LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 33,700 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 34,000 CFS.
4. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
5. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55.

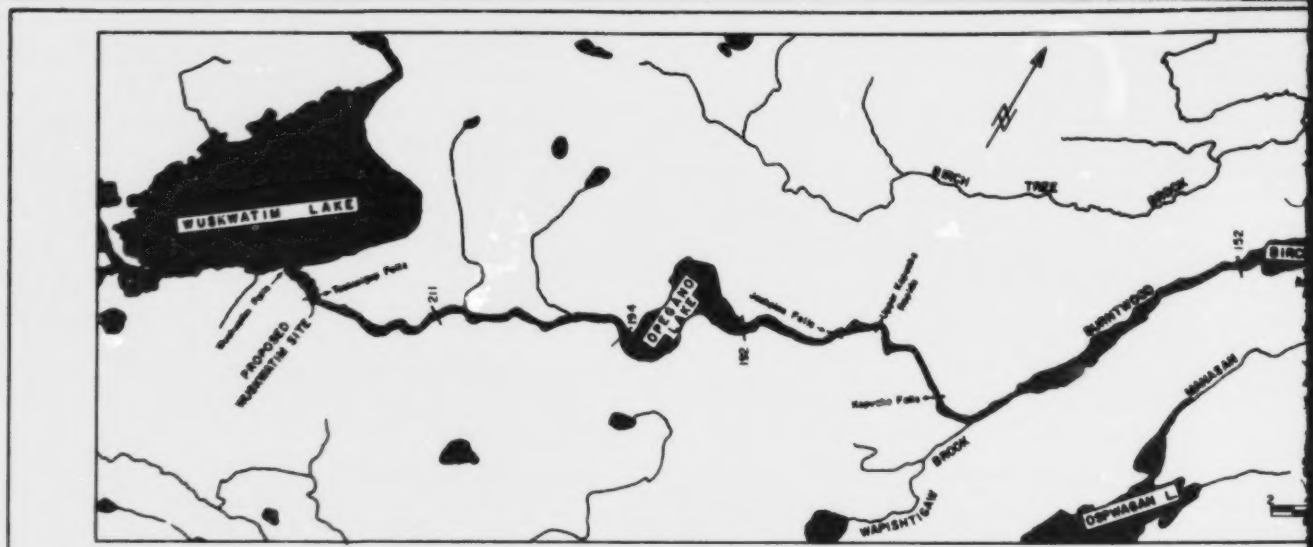
FIG. 97

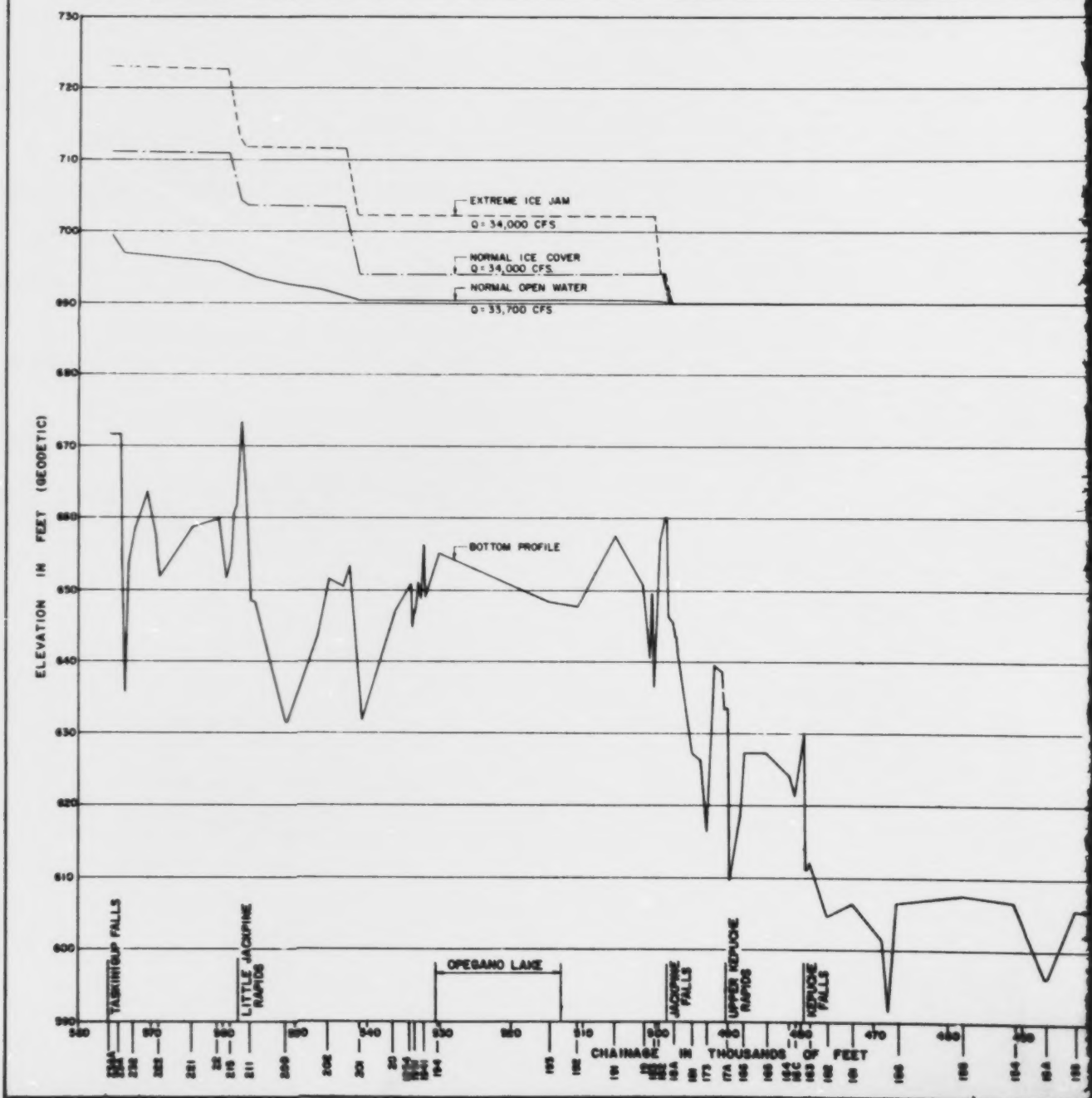
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

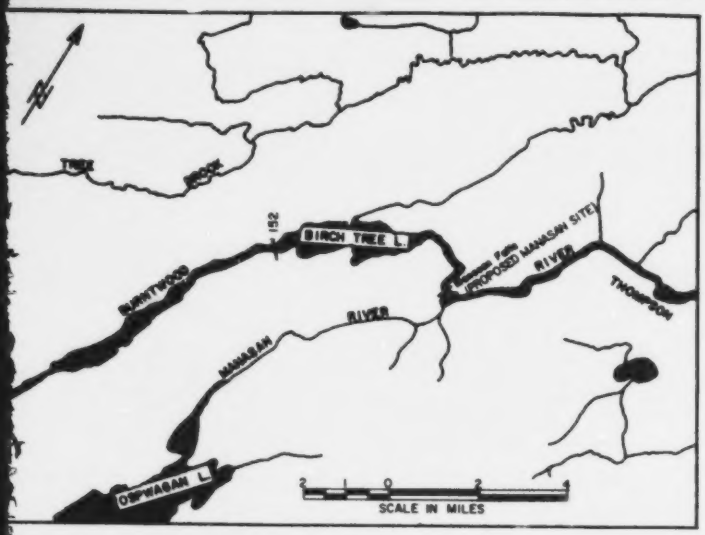
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

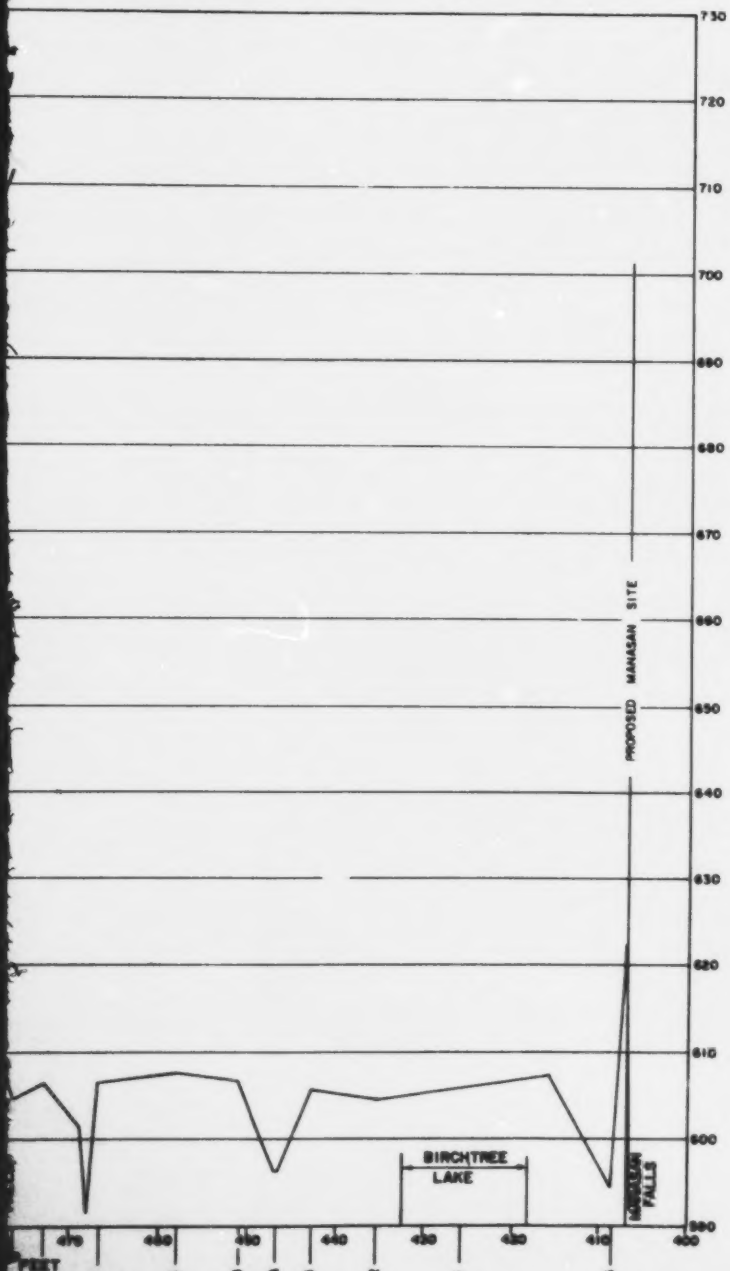
PHYSICAL IMPACT STUDY
RAT-BURNTWOOD RIVER PROFILES
WUSKWATIM TO MANASAN REACH
WITH NO MANASAN DEVELOPMENT

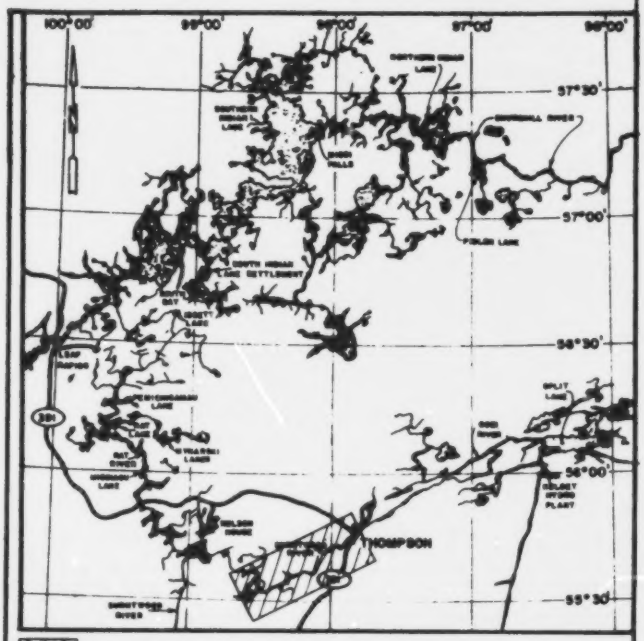
L. B.	V. K.	L. B.	DATE	DATE
AS SHOWN	FEB., 1974	17 of 58		61-1-1025


WUSKWATIM LAKE
PROPOSED HYDROELECTRIC SITE
OPEGANO LAKE
BIRCH TREE
BIRCH
EARNTWOOD
KINNAHAN
BROOK
WAPISNTIGAW
OSPWAGAN L.
211
164
152


EXTREME ICE JAM
Q = 34,000 CFS
NORMAL ICE COVER
Q = 34,000 CFS
NORMAL OPEN WATER
Q = 33,700 CFS
BOTTOM PROFILE
ELEVATION IN FEET (GEODETIC)
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
TASKINIGUP FALLS
LITTLE JACKPINE RAPIDS
OPEGANO LAKE
JACKPINE FALLS
UPPER KEPUONE RAPIDS
KEPUONE FALLS
CHAINAGE IN THOUSANDS OF FEET







= LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 33,700 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 34,000 CFS.
4. PROPOSED MANASAN FOREBAY IS ASSUMED AT ELEVATION 690.0 IN THE SUMMER AND 694.0 IN THE WINTER.
5. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
6. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55.

FIG. 98

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCE AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
RAT-BURNTWOOD RIVER PROFILES
WUSKWATIM TO MANASAN REACH
WITH MANASAN SUMMER FOREBAY AT ELEVATION 690

L.B.	V.K.	L.B.		
AS SHOWN	FEB., 1974	18 OF 58	61-1-1025	

6.3.2.3 Water Levels and Flows - Manasan to First Rapids: Burntwood River discharges undergo further change between Manasan and First Rapids by additional local inflow (Figure 99). The drainage area tributary to this reach is approximately 11% of the total drainage area of the Burntwood River above Manasan Falls. Local inflow will, therefore, be small, and the seasonal flow distribution will be similar to Burntwood River flows at Wuskwatim (Section 6.3.2.1). The maximum and minimum discharges and other significant discharge parameters at First Rapids are outlined in the following Table:

TABLE 24

BURNTWOOD RIVER DISCHARGES AT FIRST RAPIDS

	Natural	Regulated	Change
Minimum	240 cfs (Mar)	18,400 cfs (Apr)	+18,200 cfs
Mean	3,640 cfs	31,700 cfs	+28,100 cfs
Median	2,350 cfs	33,200 cfs	+30,800 cfs
Maximum	18,200 cfs (June)	36,500	+18,300 cfs
Long-term range	18,000 cfs	18,100 cfs	+ 100 cfs
Maximum monthly fluctuation:			
rise	≤20,000 cfs (June)	≤20,000 cfs (Mar to June)	
drop	≤10,000 cfs (June, July, Aug, Oct)	≤20,000 cfs (Feb to May)	
Open water mean discharge	5,870 cfs	34,270 cfs	
Winter mean discharge	1,400 cfs	29,200 cfs	

Water surface profiles for this reach are shown in Figure 100 (no hydro development at First Rapids) and Figure 101 (First Rapids forebay at 610) for the following conditions:

1. Normal natural flow. The natural mean monthly flow is 3,600 cfs and the summer mean is 5,870 cfs. The normal natural profile is, therefore, approximated by the 5,000 cfs profile shown.
2. Normal regulated flow (open water) at a mean monthly open-water discharge of 34,300 cfs.
3. Normal ice cover at the maximum winter discharge of 34,000 cfs.
4. Extreme ice jam conditions at the maximum winter discharge of 34,000 cfs.

The water levels in this reach may be represented by the levels between Apussigamasi Lake and Third Rapids and between First Rapids and Second Rapids as given in the following Tables:

TABLE 25

WATER LEVELS IN BURNTWOOD RIVER

BETWEEN APPUSSIGAMASI LAKE TO THIRD RAPIDS

Flow Condition	Development at First Rapids	
	None	Forebay at 610
Natural, open water Q = 5,000 cfs	599	610
Diversion, open water Q = 34,300 cfs	614	615
Diversion, normal ice Q = 34,000 cfs	623	623
Diversion, extreme ice jam Q = 34,000 cfs	628	628

TABLE 26

WATER LEVELS IN BURNTWOOD RIVER

BETWEEN FIRST RAPIDS AND SECOND RAPIDS

Flow Condition	Development at First Rapids	
	None	Forebay at 610
Natural, open water Q = 5,000 cfs	565	610
Diversion, open water Q = 34,300 cfs	577	610
Diversion, normal ice Q = 34,000 cfs	586	610
Diversion, extreme ice jam Q = 34,000 cfs	596	610

It is probable that the water level rise from "Diversion - open water" to "Diversion - normal ice" would occur during a period of approximatly six weeks in early winter and that the corresponding drop in the spring may take place over a period of three weeks. The extreme ice jam condition would be a rare event.

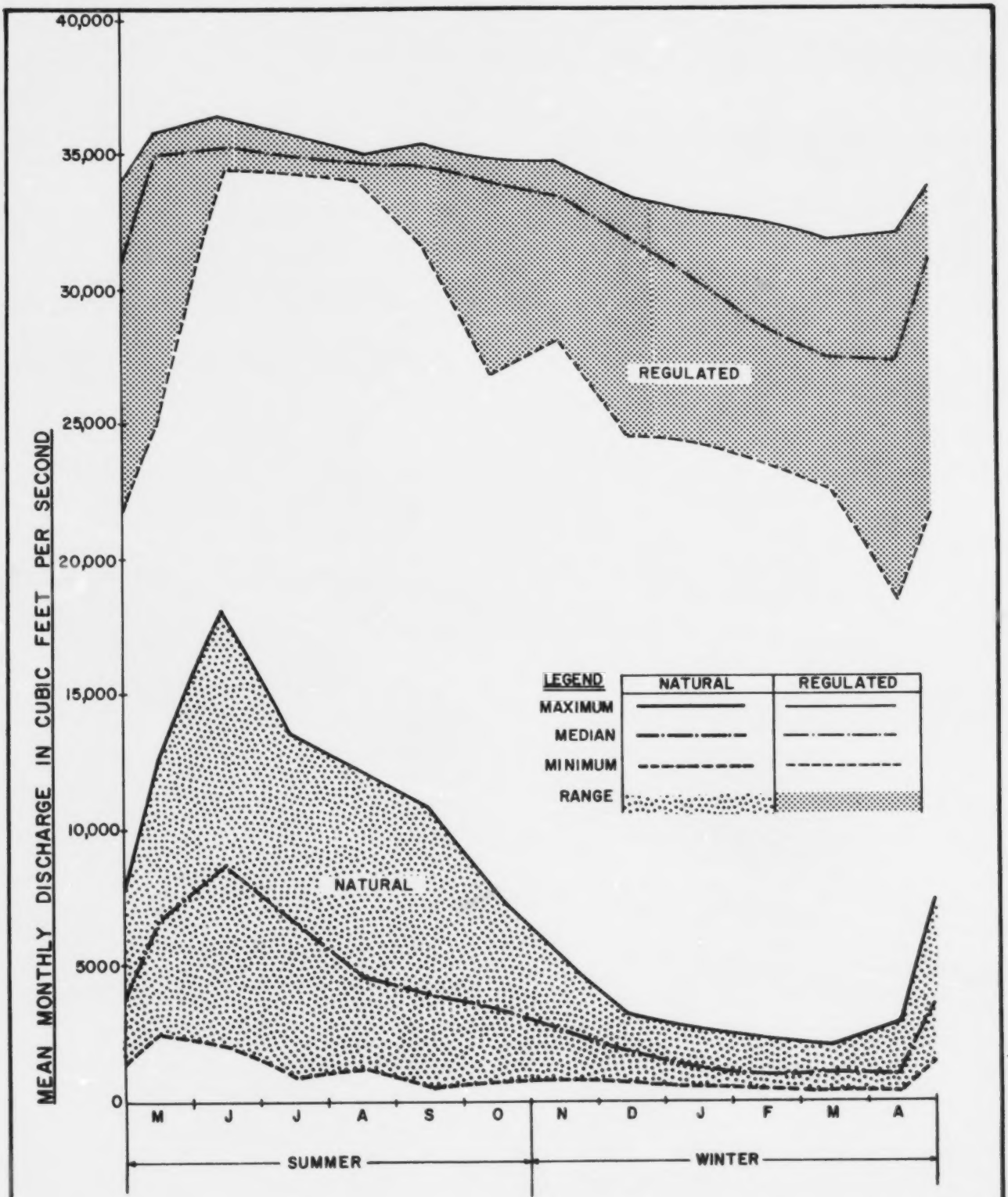
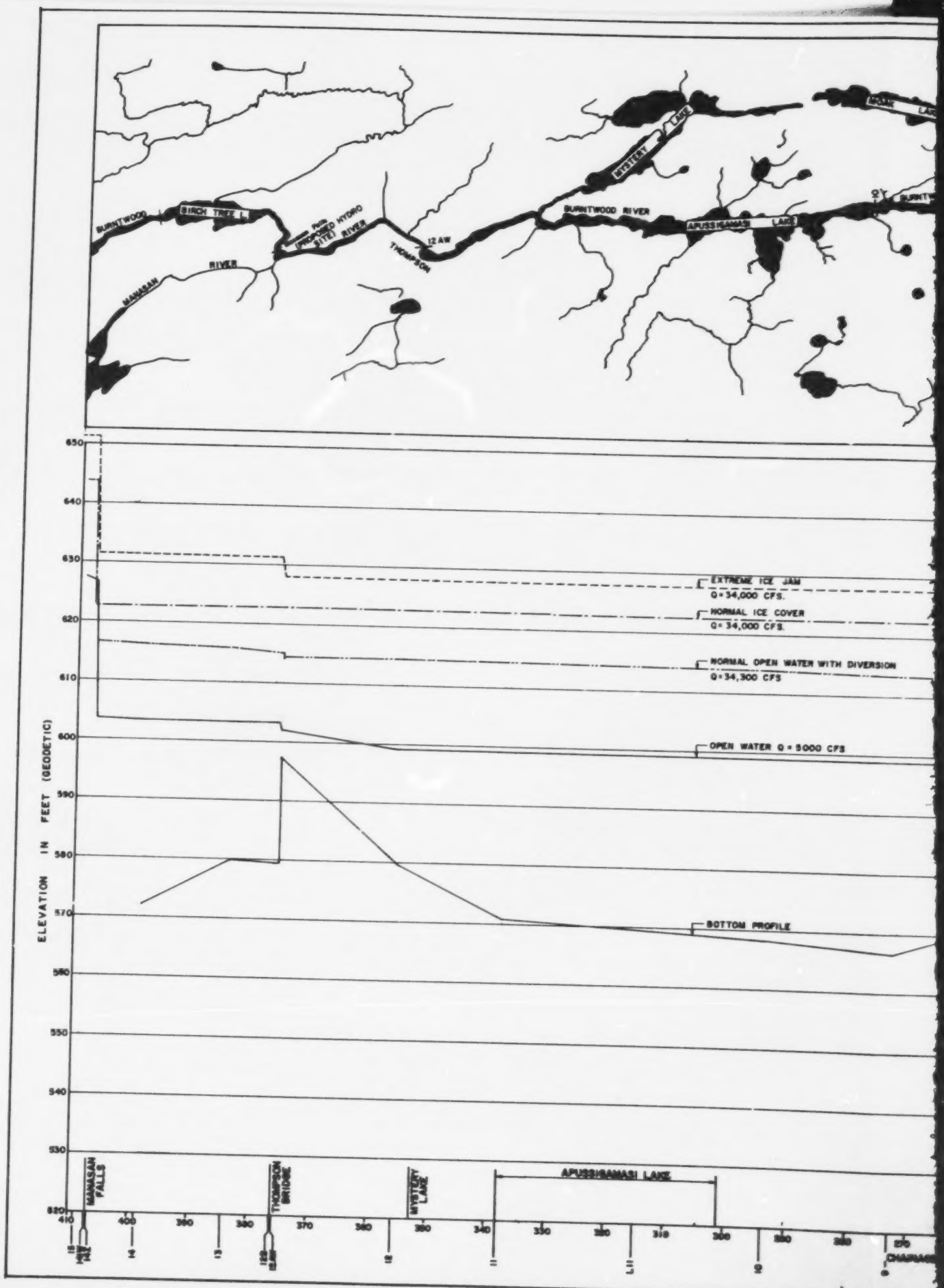
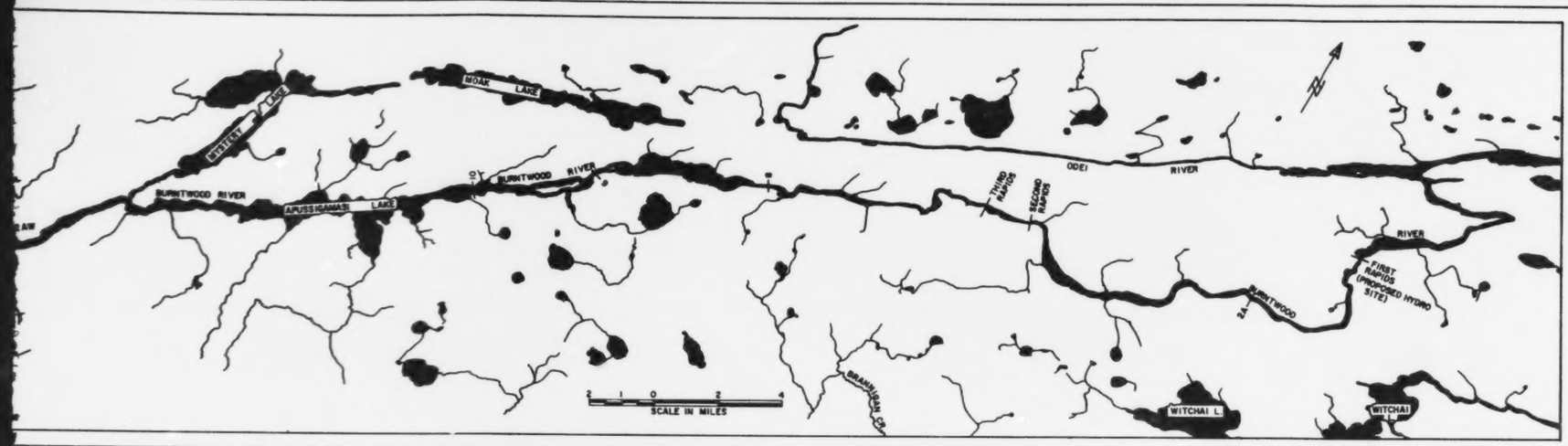
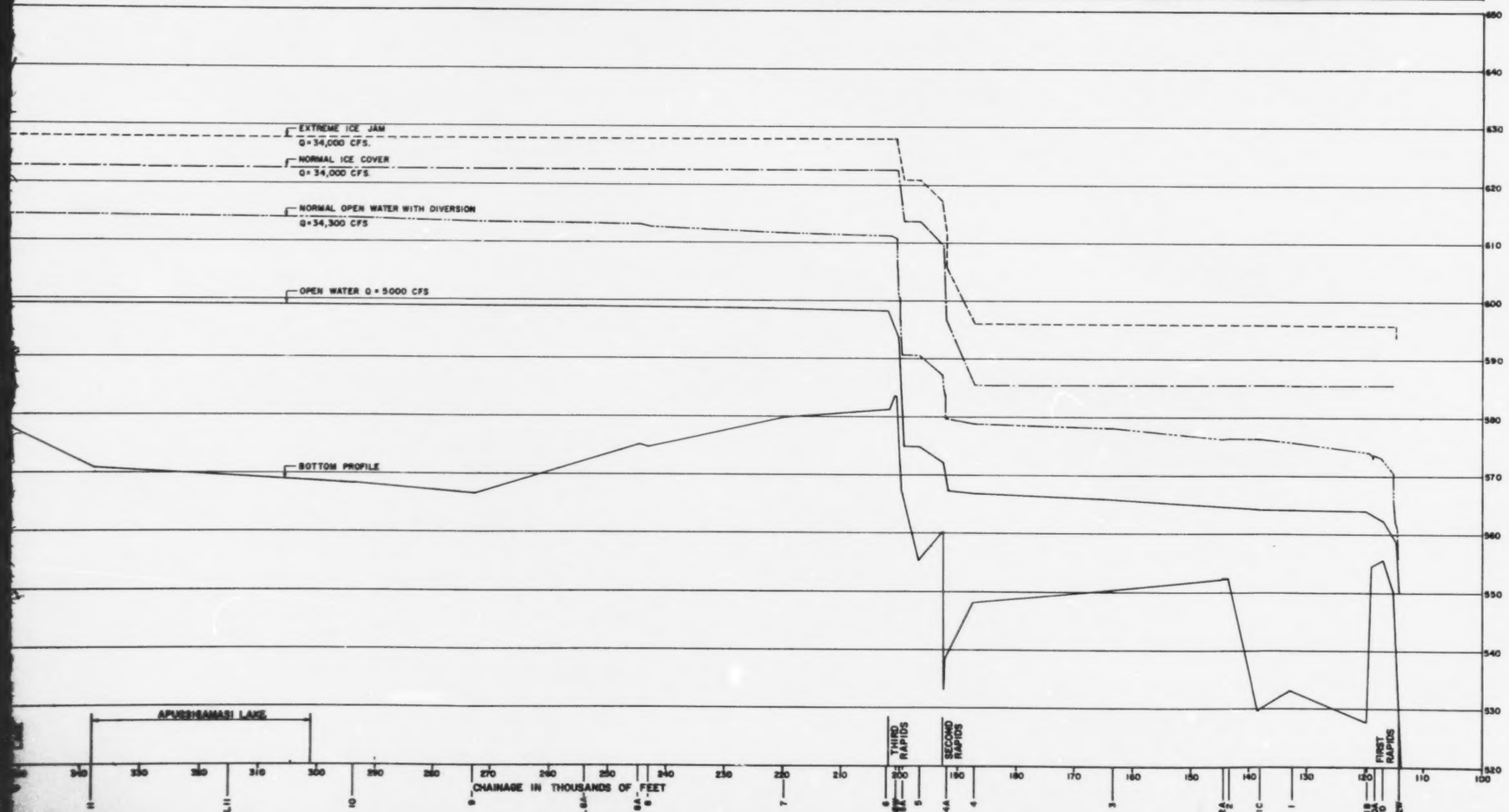


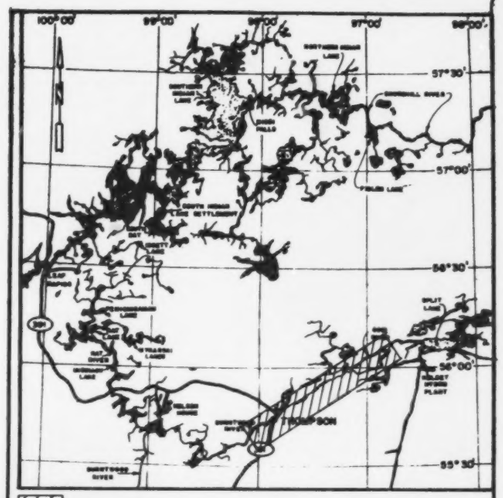
FIG. 99

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH			CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY BURNTWOOD RIVER DISCHARGES AT FIRST RAPIDS	
PREPARED L.B.	DRAWN S.P. CHECKED F.P.	SUBMITTED DATE	APPROVED DATE	SCALE
DATE JAN/74	SHEET 19 OF 58	FILE NO. 61-1-1025		


BURNTWOOD
BIRCH TREE LK.
PWR
PROPOSED HYDRO
SITE
RIVER
MANASAN
RIVER
THOMPSON
12 AW
MYSTERY
LAKE
BURNTWOOD RIVER
APUSSIGAMASI
LAKE
ELEVATION IN FEET (GEODETIC)
650
640
630
620
610
600
590
580
570
560
550
540
530
520
EXTREME ICE JAM
Q = 34,000 CFS.
NORMAL ICE COVER
Q = 34,000 CFS.
NORMAL OPEN WATER WITH DIVERSION
Q = 34,300 CFS
OPEN WATER Q = 5000 CFS
BOTTOM PROFILE
MANASAN FALLS
THOMPSON BRIDGE
MYSTERY LAKE
APUSSIGAMASI LAKE
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270







= LOCATION OF MAP

LOCATION PLAN

SCALE IN MILES

NOTES:

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 34,300 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 34,000 CFS.
4. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
5. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-95.

FIG. 100

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

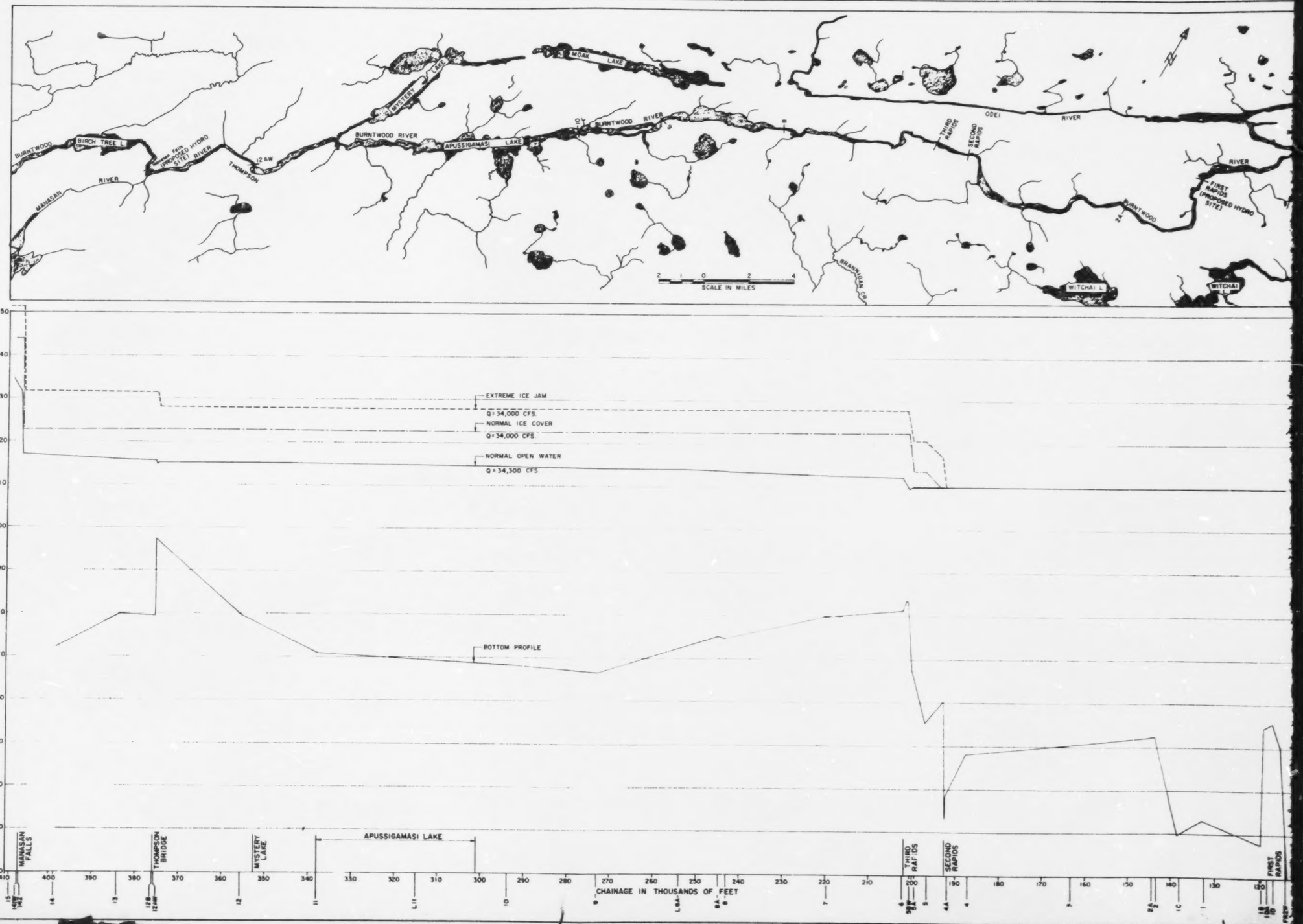
PHYSICAL IMPACT STUDY

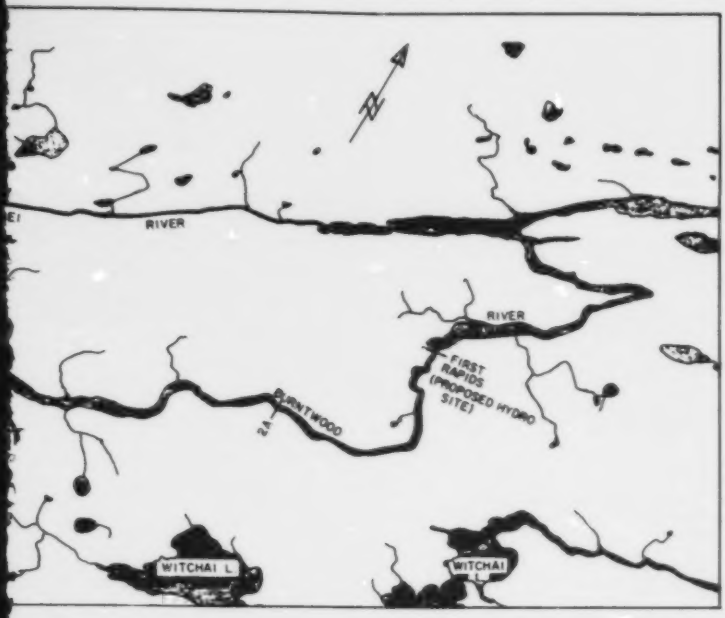
RAT-BURNTWOOD RIVER PROFILES

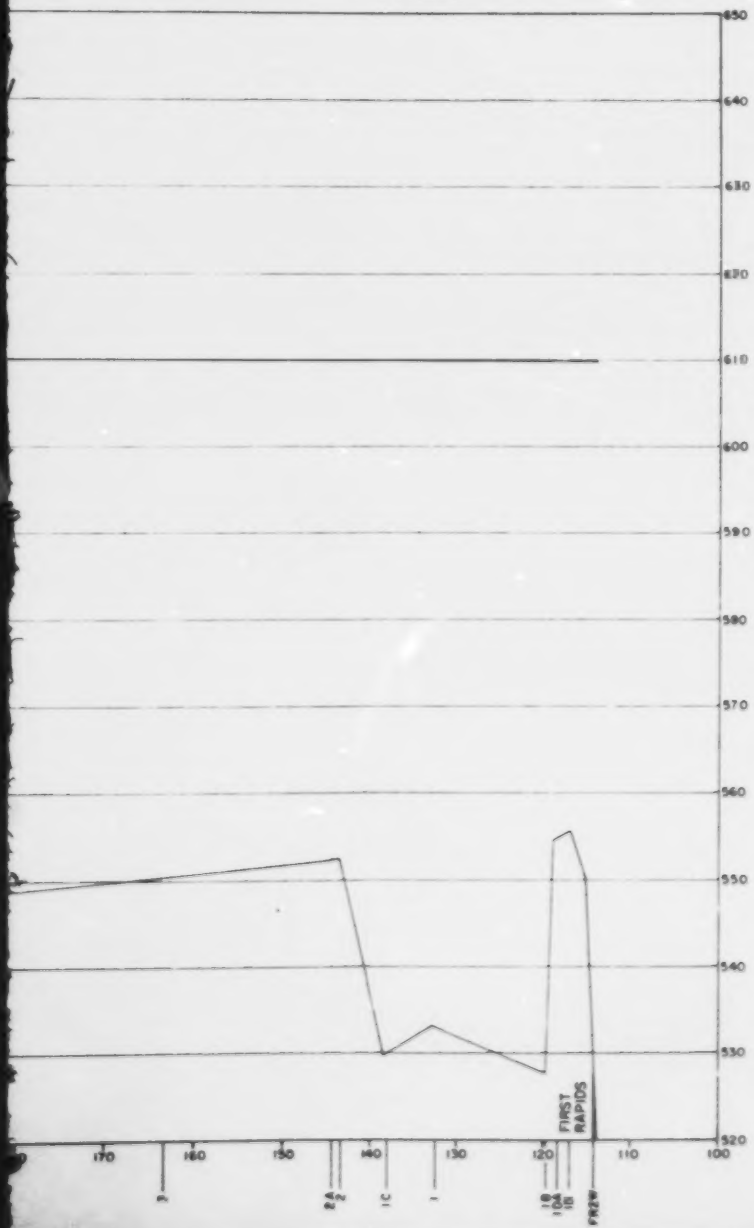
MANASAN TO FIRST RAPIDS REACH

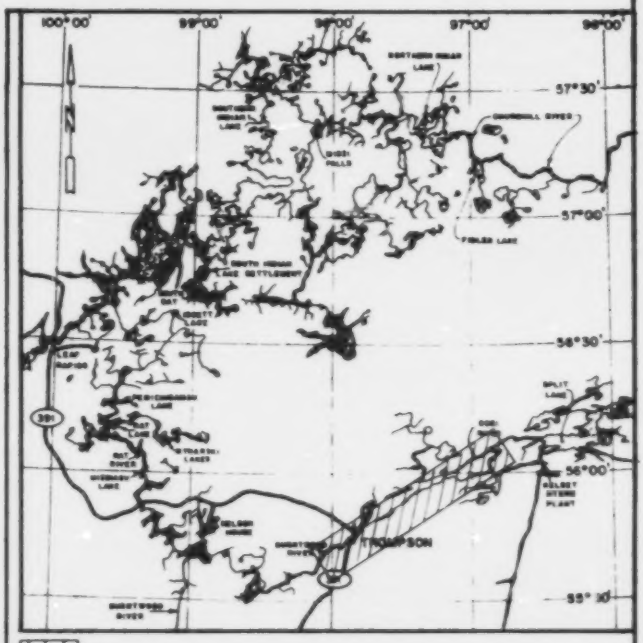
WITH NO FIRST RAPIDS DEVELOPMENT

DESIGNED	DRAWN	CHECKED	SUBMITTED	APPROVED
L.S.	V.K.	L.S.	DATE	DATE
SCALE: AS SHOWN	DATE: FEB., 1974	DRAWING NO. 20 of 58	FILE NO. 61-1-1025	


BURNTWOOD
BIRCH TREE L.
MANASAN RIVER
PROPOSED FAIN (PROPOSED HYDRO SITE) RIVER
THOMPSON
12 AW
MYSTERY LAKE
BURNTWOOD RIVER
APUSSIGAMASI LAKE
MOAK LAKE
BURNTWOOD RIVER
ODEI RIVER
THIRD RAPIDS
SECOND RAPIDS
BURNTWOOD RIVER
FIRST RAPIDS (PROPOSED HYDRO SITE)
BRANNIGAN CR.
WITCHAI L.
WITCHAI
SCALE IN MILES
2 1 0 2 4
EXTREME ICE JAM
Q = 34,000 CFS.
NORMAL ICE COVER
Q = 34,000 CFS.
NORMAL OPEN WATER
Q = 34,300 CFS
BOTTOM PROFILE
ELEVATION IN FEET (GEODETIC)
650
640
630
620
610
600
590
580
570
560
550
540
530
520
MANASAN FALLS
THOMPSON BRIDGE
MYSTERY LAKE
APUSSIGAMASI LAKE
THIRD RAPIDS
SECOND RAPIDS
FIRST RAPIDS
CHAINAGE IN THOUSANDS OF FEET
410 400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120







= LOCATION OF MAP

LOCATION PLAN

0 20 40 60

SCALE IN MILES

NOTES

1. ALL PROFILES ARE DERIVED FROM MANITOBA HYDRO REPORT ON WATER AND ICE ELEVATIONS IN THE RAT-BURNTWOOD RIVER SYSTEM, DECEMBER 1973.
2. NORMAL OPEN WATER PROFILE WITH DIVERSION WAS DEVELOPED FOR A DISCHARGE OF 34,300 CFS BY INTERPOLATION FROM MANITOBA HYDRO BACKWATER CURVES.
3. ICE COVER PROFILES WITH DIVERSION ARE DRAWN FOR THE MAXIMUM WINTER DISCHARGE OF 34,000 CFS.
4. PROPOSED FIRST RAPIDS FOREBAY IS ASSUMED AT ELEVATION 610.
5. BOTTOM PROFILE IS TAKEN AT THE DEEPEST POINT IN THE RIVER CROSS-SECTION.
6. FOR LOCATION OF CROSS-SECTIONS, SEE MANITOBA HYDRO DRAWING NUMBER 7001-R-55.

FIG. 101

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
RAT-BURNTWOOD RIVER PROFILES

MANASAN TO FIRST RAPIDS REACH

WITH FIRST RAPIDS FOREBAY AT ELEVATION 610

PREPARED	DESIGN	CHECKED	SUBMITTED	APPROVED
L.D.	Y.K.	L.D.	DATE	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	FEB., 1974	21 OF 58	61-1-1025

6.3.2.4 Water Levels and Flows - First Rapids to Split Lake: Burntwood River discharges are augmented in this reach by a contribution from the Odei River. This tributary drains more than one-quarter of the total Burntwood River drainage area above Split Lake and represents a significant inflow.

Estimated natural and regulated discharges at Split Lake are presented in Figure 102. As with the rest of the Burntwood system highest natural monthly discharges (as great as 25,000 cfs) occur in June. Flows then decrease during late summer to a late-winter low. The seasonal variation with regulation will be similar, with maximum discharges as great as 42,600 cfs in June, decreasing during late summer, with mid-winter lows.

Short-term fluctuations (monthly variations) have not been calculated, but will probably be slightly greater than those at First Rapids due to fluctuations in local inflow. These short-term, monthly, changes may be assumed to be approximately the same as those at First Rapids (Section 6.3.2.3).

The following Table summarized the various hydraulic parameters for this reach:

TABLE 27

BURNTWOOD RIVER DISCHARGES AT SPLIT LAKE

	Natural	Regulated	Change
Minimum	300 cfs (Mar)	18,600 cfs (Apr)	+18,300 cfs
Mean	5,000 cfs	33,100 cfs	+28,100 cfs
Median	3,200 cfs	34,000 cfs	+30,800 cfs
Maximum	25,000 cfs (June)	42,600 cfs (June)	+17,600 cfs
Long-term range	24,700 cfs	24,000 cfs	- 700 cfs
Open water mean discharge	8,050 cfs	36,400 cfs	
Winter mean discharge	1,900 cfs	29,700 cfs	

The water levels in this reach of the river are given approximately in the following table. Diversion flows are expected to increase the levels under the various conditions by two to six feet. Ice effects are not expected to raise water levels substantially in this reach.

TABLE 28

WATER LEVELS IN BURNTWOOD RIVER

FROM FIRST RAPIDS TO SPLIT LAKE

Condition	Flow in Nelson River downstream of Split Lake	Flow in Burntwood River	Elevation of Burntwood River Downstream of First Rapids	Elevation of Burntwood River At Split Lake
Natural minimum	25,000 cfs	300 cfs	542	542
Natural median	80,000 cfs	5,000 cfs	546	545.6
Natural maximum	173,000 cfs	25,000 cfs	553	551.6
Regulated minimum	60,000 cfs	18,600 cfs	547.5	544.3
Regulated median	110,000 cfs	33,100 cfs	552.5	547.5
Regulated maximum	216,000 cfs	42,600 cfs	557	554.4

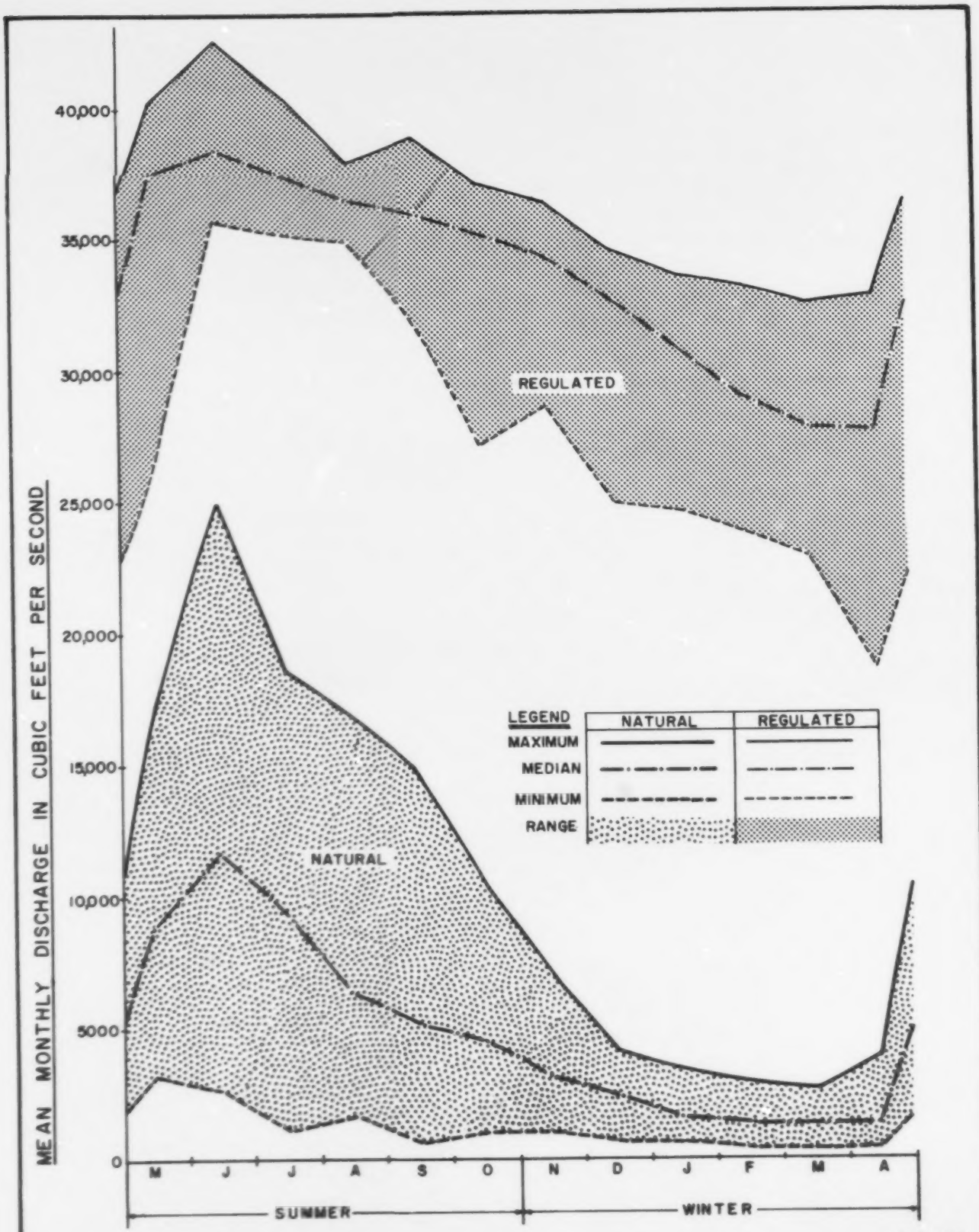


FIG. 102

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
BURNTWOOD RIVER DISCHARGES AT SPLIT LAKE

PREPARED	DRAWN	SUBMITTED	
L.B.	S.P.		
CHECKED	F.P.	DATE	DATE

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN/74	22 OF 58	61 - 1 - 1025

6.3.3 IMPACTED STATE CONDITIONS - NOTIGI TO SPLIT LAKE:

6.3.3.1 Impacted State Conditions - Rat and Burntwood Rivers - Notigi to Split Lake: The impact statements in this section are based on the effect of increased flows - they do not include the effects of possible future reservoirs at Wuskwatim, Manasan and First Rapids.

TABLE 29

LAKE LEVELS - NOTIGI TO SPLIT LAKE (feet)

Flow Condition	Wapisu	Threeepoint	Wuskwatim	Opegano	Birchtree
Natural, open water Q = 5,000 cfs	786.5	784.5	758	678	628
Diversion, open water Q = 33,400 cfs	802	800	768	685	636.5
Diversion, normal ice Q = 33,200 cfs	813	812	777	694	644
Diversion, extreme ice jam Q = 33,200	820	820	783	702	652
Flooding, open water	16	16	10	7	8.5
Flooding, normal ice	27	28	19	16	16

Shorelines: The several lakes included in this reach will have changes in water levels as outlined in the following table:

An increase in open-water on these lakes will result in impacts of flooding and erosion as outlined in Section 5.4 under low-level flooding.

A second, and possibly more important, effect will be produced by the winter ice regime of the Burntwood River following diversion. High discharges during the winter, combined with the formation of an ice cover on the channel, are expected to result in water levels during the winter which are about ten feet higher than maximum summer levels throughout the whole of the river system. Winter lake levels on the system will also be ten feet higher than highest summer levels. This effect is rarely observed on lakes in the natural state and is expected to have serious implications for this seasonally flooded zone. Ice cover formation on lakes begin initially at the shoreline. On the Lakes along the Burntwood River, rises in water level are expected during lake freeze-up as the downstream river channels become ice-covered. The border ice, buoyed up by the rising water, will rise. In the spring, the reverse effect is expected. Dropping water levels are expected as the river ice cover breaks up before the lake cover is completely melted. The remaining ice on the lakes will then drop with the water level. In addition, movement of ice flows by wind at these water levels will aggravate the effects of the ice cover fluctuations.

The effects of higher winter levels and ice movements have been observed on the Kettle Generating Station forebay. On this forebay, reservoir operation during the two years of operation has called for the raising of water levels by about four feet in the early winter after a ice cover has established. Water levels are lowered back to summer levels in the spring just before general break-up occurs. The ice cover by this time is "rotten" or weakened by melting, to a great degree.

The effects of these fluctuations during the winter of 1971 to 1972 have been reported briefly by Manitoba Hydro personnel. Break-up in 1972 reportedly resulted in the removal of some branches from trees in the forebay. Stripping of bark from the trunks of trees was widespread.

Further fluctuations occurred during the winter of 1972 to 1973. An experimental program during that season called for the lowering of the level in mid-winter, with an ice cover approximately one foot thick. This was done "to crush trees in the forebay and proved effective". Raising the level again in January, with an ice cover two feet thick, uprooted a few trees. The major effect reported was stripping of bark from a great many trees in the zone of fluctuation and removal of a small percentage affected trees. The most severe effects were observed at the reservoir side of the zone of standing trees. Movement of ice flows during spring break-up was indicated to be a major force in falling trees within this zone.

Field observations after two winters of these fluctuating ice levels confirmed these reports and indicated some major implications for vegetation in the affected zone. Three major effects were observed.

Vegetation in the winter-flooded zone was affected directly by flooding. As this is the dormant season for vegetation, death by flooding would not normally be expected for most species, at least during the first few years. Less tolerant species had succumbed to the higher levels after two years. Less tolerant species had succumbed to the higher levels after two winters. Labrador tea and Sphagnum had died in a zone well above the summer wave-washed zone. Although this effect could be partially a result of raising the summer water table higher into this environment, the fact that this zone consistently ended at maximum winter levels suggests that death is largely due to flooding in winter. Death of alder shrubs in this zone due to winter flooding and crushing by ice was also observed, but to a lesser degree.

Death of larger trees in this zone is expected. Stripping of phloem, or the layer that supplies food to the tree roots, soon kills affected trees. This effect was observed on Kettle forebay banks in sites where bark removal had occurred. The rates at which these processes occurred suggests that spruce trees on most sites would be killed within the first five years. Poplars generally appeared to be more resistant to the mechanical stripping, and would not be expected to die as soon. No instances of poplar death had been observed.

Removal of trees in this zone is an important consideration. The seasonal fluctuation, compounded by drifting ice in the spring especially on more exposed sites, had knocked over some of the trees within this zone. This effect is expected to increase as the trees die and are weakened. This effect is largely

dependent on the condition of the ice cover as levels are raised and lowered.

Bank erosion at the higher winter levels is generally restricted by ice cover and frozen banks. Erosion effects are largely determined by timing of the fluctuations in relation to melting of the ice cover. Open water exists in sites where the cover is well anchored and flooding of the cover occurs. Effects on the Kettle Reservoir were limited to one or two sites of local scour.

Winter effects are illustrated in Photographs 98, 99 and 100, taken on the Kettle Rapids forebay. Much the same effects are expected along the whole diversion route, with the ten-foot zone of winter flooding. The actual sequence of ice cover formation and water level rises is somewhat unclear at this time, and impacts may be modified somewhat. Trees within this zone are expected to die within five years on most sites. Shrubs and mosses will be directly affected and will soon die. Tree removal will be fairly rapid on more exposed sites, and may be complete within ten to twenty years. Embayments afford some protection from these effects.

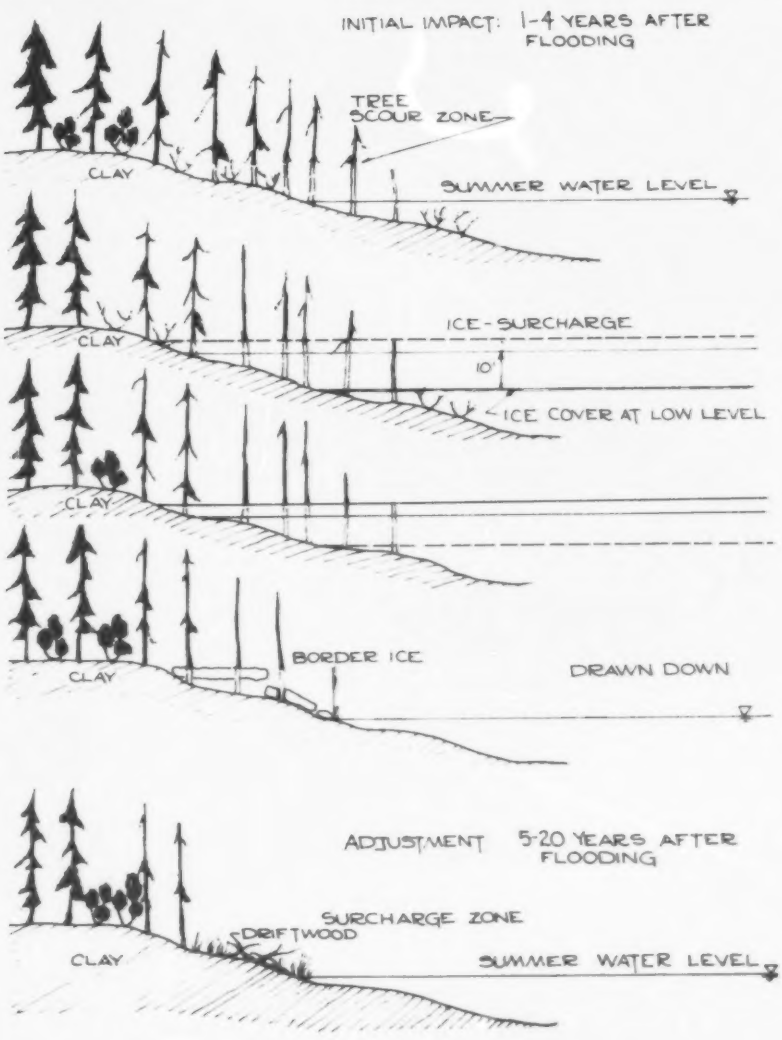
The ice scoured bank effect on the lower Nelson River was observed to extend into tributary streams to the same elevation as on the River, indicating that a winter rise in water level in itself is adequate to prevent the growth of trees and larger shrubs within the zone of water level rise. That is, the tremendous horizontal thrusts of the ice sheet against the shoreline such as are generated in the main stem of the River by ice jaming are not essential to produce the ice scoured zone. Thus the ice scoured bank effect is expected to develop along all shorelines subject to a winter rise in ice level. The lateral and tangential ice thrusts, where they develop along channel sections are, however, expected to accelerate the development of the ice scoured zone. Hence, river shorelines are expected to develop the ice scoured zone sooner than lake shorelines.

The anticipated effects of the ice surcharge on the Burntwood River are illustrated in Figure 103.

PHOTOGRAPH 98 - Kettle Rapids forebay. Dead shrubs in the winter-flooded zone.

PHOTOGRAPH 99 - Kettle Rapids forebay. Stripped bark and felled trees in winter-flooded zone. Note death of spruce trees and living trees in background in same zone.

PHOTOGRAPH 100 - Local erosion of till bank at winter levels. Dead trees on the bank have been previously killed by a fire in this area. The higher eroded zone corresponds to winter levels.



EFFECTS OF ICE SURCHARGE ON THE BURNTWOOD RIVER WITH DIVERTED WATER FLOWS

FIGURE 103

River Channels: The estimate of increase in channel dimensions presented in this section may be applied as a first approximation to the total length of the Rat-Burntwood River from Notigi to Split Lake.

In general terms, the increase in discharge may be expected to result in an increase in channel size for an alluvial section. The relationships between channel dimensions and representative or "formative" discharge have been defined in the following general equations:

$$w \propto Q^a \text{ - - - - - - - (1)}$$
$$d \propto Q^b \text{ - - - - - - - (2)}$$
$$\text{and } v \propto Q^c \text{ - - - - - - - (3)}$$

where: w is the stream width,
d is the average depth,
v is the stream velocity,
a, b and c are exponents less than 1.0,
and Q is a representative, or "formative" discharge for the channel, not necessarily equal to the mean discharge.

Based on a large number of streams of various discharges and material composition, mean values for these exponents have been determined. These values are:

a = 0.5
b = 0.3 to 0.4 (most values are nearer to 0.4) and
c = 0.1 to 0.2

The most uncertain parameter in these equations is Q, the formative discharge for a given stream. This discharge is rarely equal to the mean discharge. For many rivers, it may be near the mean annual flood. For cohesive-bed rivers carrying largely suspended sediment, it may be a considerably greater discharge, as deposition of these fine materials does not occur readily during periods of low flows. This is similar to the Burntwood River case.

Investigations by Underwood & McLellan (Reference 12) have indicated a formative discharge near 20,000 cubic feet per second for the Burntwood River at Thompson, based on channel characteristics. This corresponds roughly to the 10 percent flood (Figure 104), or a flood peak with a probability of occurring once in ten years. For the clay materials along the Burntwood channel, this is thought to be a reasonable estimate of the formative discharge. For the purpose of analysis, this value has been accepted.

Under regulation, discharges will be fairly constant throughout the river system. Maximum discharge will be approximately 35,000 cubic feet per second throughout most of the diversion route. Mean discharges will be only marginally less. The channel is, therefore, assumed to adjust to a formative discharge of 35,000 cubic feet per second after diversion.

Substitution of these discharges into the general equations will give an indication of the ultimate equilibrium channel shape for a 35,000 channel, as outlined below:

From Equation 1:

$$\frac{w_2}{w_1} = \left[\frac{Q_2}{Q_1}\right]^{0.5} = \left[\frac{35,000}{20,000}\right]^{0.5} = 1.32 \text{ - - - (4)}$$

i.e. future channel width will be approximately 30% greater than the present width at 20,000 cubic feet per second.

From Equation 2:

$$\frac{d_2}{d_1} = \left[\frac{Q_2}{Q_1}\right]^{0.3 \text{ to } 0.4} = \left[\frac{35,000}{20,000}\right]^{0.3 \text{ to } 0.4} =$$

$$= 1.18 \text{ to } 1.25 \text{ - - - (5)}$$

i.e future mean depth will be approximately 20% greater than the present mean depth at a discharge of 20,000 cubic feet per second.

The ratio of cross-sectional areas is given approximately by:

$$\frac{A_2}{A_1} = \frac{w_2}{w_1} \times \frac{d_2}{d_1} = 1.32 \times (1.18 \text{ to } 1.25) =$$
$$= 1.56 \text{ to } 1.65 \text{ - - - } (6)$$

The effect on channel slope or tendancy to meander is given by subsituting into Manning's equation in the form:

$$S = \left[\frac{Qn}{1.49\ AR^{2/3}}\right]^2 \text{ - - - - } (7)$$

where n is a roughness constant,
R is the hydraulic radius and is approximately equal to the mean depth, d, and
S is the energy slope and is approximately equal to the channel slope in an alluvial channel.

With a constant n-value, and the ratios calculated above:

$$\frac{S_2}{S_1} = \left[\frac{Q_2}{Q_1} = \frac{A_1}{A_2}\ \left(\frac{R_1}{R_2}\right)^{2/3}\right]^2 =$$

$$= \left[\frac{1.75}{(1.56 \text{ to } 1.65) \times (1.18 \text{ to } 1.25)^{2/3}}\right]^2 =$$

= 1.0 to 0.84, depending on the choice of values for b in equation (2).

i.e. little, if any, change in channel alignment will occur.

Also, from Equation 3, future channel velocity is given by:

$$\frac{v_2}{v_1} = \left(\frac{Q_2}{Q_1}\right)^{0.1 \text{ to } 0.2} = \left(\frac{35{,}000}{20{,}000}\right)^{0.1 \text{ to } 0.2}$$

= 1.06 to 1.12

i.e future velocity will be approximately 10% greater than present velocity at 20,000 cubic feet per second.

It must be emphasized here that the ratios given by these equations are ratios of the dimension of a channel having a formative discharge of 35,000 cfs to the corresponding dimension of a channel with a formative discharge of 20,000 cubic feet per second. This does not give directly the magnitude of the horizontal and vertical recessions involved. Also, these relationships are strictly applicable for channel sections with no bedrock controls.

In order to determine characteristic dimensions for the existing channel, all sections which were classified as Type 23 (clay shoreline of moderate height and mild slopes) and Type 14 (bedrock-controlled shoreline) were examined. Graphs relating width and depth to discharge under the present channel regime were plotted for more than forty cross-sections. Depth and width data for this analysis were obtained from computer print-outs of Manitoba Hydro's backwater studies. A great deal of variability was observed, with bedrock outcrops affecting to a great degree the channel characteristics in most locations.

Four basic channel types were observed. These are outlined below:

1. Alluvial Channel in Regime - For this type, bedrock control is thought to be absent or minor; channel dimensions are determined by discharges and material composition. The width and hydraulic mean depth (or cross-sectional area divided by surface width) for the existing stream channel for nine sections of the type are summarized in the following table:

TABLE 30

EXISTING SURFACE WIDTH AND MEAN DEPTH FOR ALLUVIAL CHANNELS IN REGIME

Section Number	Q = 20,000 cfs Width	Depth	Q = 35,000 cfs Width	Depth
U40	690 feet	18 feet	720 feet	22 feet
U42	670 feet	16 feet	750 feet	19 feet
19	620 feet	18 feet	670 feet	22 feet
186	600 feet	21 feet	650 feet	22 feet
185	600 feet	17 feet	650 feet	18 feet
184	630 feet	19 feet	680 feet	20 feet
14	600 feet	21 feet	640 feet	24 feet
13	580 feet	18 feet	680 feet	20 feet
9	650 feet	20 feet	720 feet	23 feet
Mean	625 feet	19 feet	685 feet	21 feet

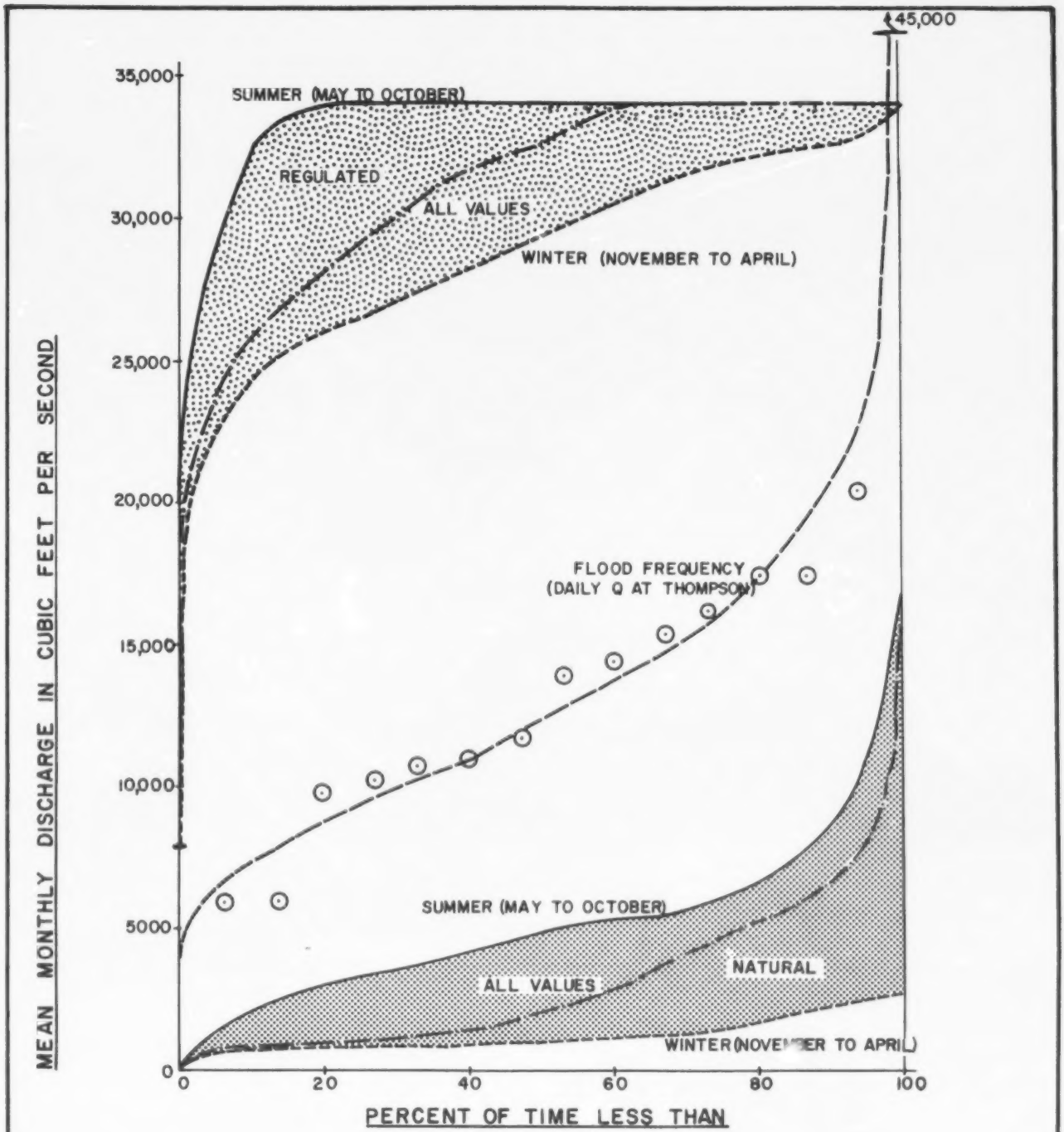


FIG. 104

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY DISCHARGES OF THE RAT-BURNTWOOD DIVERSION AT WUSKWATIM
PREPARED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE APPROVED DATE	SCALE AS SHOWN DATE JAN/76 SHEET 23 OF 58 FILE NO. 61-1-1025

The regime equation predicts the future width for 35,000 cfs to be 1.32 time the existing width at 20,000 cfs or 1.32 x 625 = 825 feet. The existing width for a discharge of 35,000 cfs is 685 feet. Hence, the channel may erode 140 feet laterally or each bank may receed 70 feet.

The regime equation predicts the future mean depth for 35,000 cfs to be 1.18 to 1.25 time the existing mean depth at 20,000 cfs or 1.25 x 19 = 24 feet. The existing mean depth for a discharge of 35,000 cfs is 21 feet. Hence, the channel may erode three feet vertically.

It should be noted that these values indicate the ultimate net change that will take place as the channel shape adjusts, and does not indicate the time required. These changes may not be completed for many years to come. In the short term major channel erosion will be bed erosion, and will initially deepen the channel to beyond the depth indicated above. Ultimately horizontal adjustments will occur and mean depth will approach the indicated values as deposition occurs or water levels drop with the increased width.

Approximately half of the channel sections of this type have been mapped as Type 14, the rest as Type 23. Not all Type 14 or 23 shorelines are of this type, however.

2. Bedrock-controlled Channel - These channel sections are controlled either horizontally or vertically by bedrock constrictions of channel width, and in most cases occur throughout a relatively short length of channel between two sets of rapids. The bedrock outcrops have a moderate to extensive effect on surface width and mean depth in these sections. These sections are generally somewhat narrower than alluvial sections in a regime.

The surface width and hydraulic mean depth versus discharge data are summarized in the following table for the present channel shape at eleven cross-sections of this type:

TABLE 31

EXISTING SURFACE WIDTH AND MEAN DEPTH FOR BEDROCK CONTROLLED CHANNELS

Section Number	Q = 20,000 cfs Width	Depth	Q = 35,000 cfs Width	Depth
U68	380 feet	18 feet	400 feet	20 feet
27	420 feet	20 feet	450 feet	22 feet
U70	400 feet	20 feet	430 feet	21 feet
25	390 feet	20 feet	430 feet	22 feet
183	600 feet	20 feet	610 feet	22 feet
182	540 feet	18 feet	550 feet	20 feet
17	400 feet	18 feet	430 feet	21 feet
165	500 feet	17 feet	550 feet	19 feet
12B	540 feet	21 feet	580 feet	24 feet
8	360 feet	22 feet	350 feet	26 feet
7	480 feet	18 feet	530 feet	22 feet
Mean	455 feet	19 feet	485 feet	22 feet

Both width and depth are variable, and depend on the degree of bedrock control. Sections with only minor degrees of control will approach the alluvial channel situation. For most of the sections of this type examined, the river width and depth were fairly consistent, and averaged 455 and 19 feet.

The variation of width and depth with dominant discharge is not certain. The magnitude is not expected to be as great as for alluvial sections in a regime due to the effect of controls. The effect can be expected to be proportional, ie. higher discharges will result in a larger channel section, though not as great as an alluvial section in regime.

The regime equation predicts the future width for 35,000 cfs to be 1.32 times the existing width at 20,000 cfs or 1.32 x 455 = 600 feet. The existing width for a discharge of 35,000 cfs is 485 feet. Hence, the channel may erode 115 feet laterally or each bank may recede about 60 feet.

The regime equation predicts the future mean depth for 35,000 cfs to be 1.18 to 1.25 the existing mean depth for 20,000 cfs or 1.25 x 19 = 24 feet. The existing mean depth for a discharge of 35,000 cfs is 22 feet. Hence, the channel may erode two feet vertically.

Channel sections of this type have almost invariably been mapped as Type 14 shorelines. The one exception has been mapped as Type 23.

3. Lake-controlled Channel - These sections occur upstream and downstream of the lakes, and mark a gradual widening of the channel in the transition of the lake section as the stream flow spreads into the lake.

Width and depth variation with discharge for sections of this type located near Opegano Lake are summarized in the following table:

TABLE 32

EXISTING SURFACE WIDTH AND MEAN DEPTH FOR LAKE CONTROLLED CHANNELS

Section Number	Q = 20,000 cfs Width	Depth	Q = 35,000 cfs Width	Depth
20	740 feet	20 feet	760 feet	22 feet
1954	900 feet	19 feet	930 feet	21 feet
1953	890 feet	20 feet	910 feet	22 feet
1952	860 feet	20 feet	870 feet	23 feet
1951	870 feet	20 feet	900 feet	22 feet
1945	710 feet	19 feet	740 feet	21 feet
1944	700 feet	21 feet	720 feet	23 feet
1943	790 feet	19 feet	850 feet	20 feet
1942	770 feet	16 feet	800 feet	18 feet
1941	790 feet	20 feet	820 feet	22 feet
195	760 feet	16 feet	790 feet	18 feet
194	670 feet	15 feet	720 feet	17 feet
191	780 feet	16 feet	830 feet	18 feet
Mean	790 feet	18.5 feet	820 feet	20.5 feet

The regime equation predicts a future width for 35,000 cfs to be 1.32 time the existing width at 20,000 cfs or 1.32 x 790 = 1040 feet. Similarly the regime equation predicts the future mean depth for 35,000 cfs to be 1.18 to 1.25 the existing mean depth for 20,000 cfs or 1.25 x 18.5 = 23 feet. However, the regime equation for width is not considered applicable in this case.

This existing and predicted future depth for the three types of channels are summarized in the following table:

TABLE 33

EXISTING AND PREDICTED FUTURE WIDTH AND MEAN DEPTHS FOR BURNTWOOD RIVER CHANNELS

Channel Type	Existing Q = 20,000 cfs Width	Depth	Existing Q = 35,000 cfs Width	Depth	Predicted Future Q = 35,000 cfs Width	Depth
Alluvial	625 feet	19 feet	685 feet	21 feet	825 feet	24 feet
Bedrock Controlled	455 feet	19 feet	485 feet	22 feet	600 feet	24 feet
Lake Controlled	790 feet	18.5 feet	820 feet	20.5 feet	1040 feet (N.A.)	23 feet

The existing width of the lake controlled channel for 35,000 cfs (820 feet) is not much greater than the existing width for 20,000 cfs (790 feet) suggesting the width is not very sensitive to discharge. Furthermore, the existing width of the lake controlled channel for 35,000 cfs (820 feet) is about equal to the future width (as predicted by the regime equation) of the alluvial channel for 35,000 cfs (825 feet) suggesting that little erosion is to be expected. Hence, the regime equation for future width is not considered applicable to the lake controlled channels. Little lateral erosion is anticipated at these sections.

The vertical erosion of two to three feet suggested by the regime equation appears probable since the existing and future mean depths for the lake controlled channels agree with the corresponding mean depths for alluvial and bedrock controlled channels.

All channel sections of this type have been mapped as Type 23 shorelines.

4. Irregular Channel - This channel type included all those sections not described by the three classes above. This included sections at the mouths of tributary streams, sections with bedrock banks, sections just downstream of rapids or falls in the turbulent zone, and deposition sections with wide offshore shallows as found at many sites on the lower Burntwood. In this case, the channel shape cannot be directly related to the discharge.

In many cases, increased discharges will mean minor changes in the shoreline. Sections downstream of rapids or falls, for example, are generally Type 13 (Low Bedrock Shorelines). Little or no recession can occur on this shoreline with higher levels. Tributary mouths occur at wider channel sections with mild banks. Little or no change in width can be expected at such a section. Channel depth may be expected to increase. Bedrock shoreline of Type 13 and 11 are controlled by the occurrence of bedrock. Almost no recession may be expected.

Sections of the type found along the lower Burntwood with wide offshore shallows are wider than alluvial sections in regime at higher discharges. Adjustments may be expected in the channel dimensions to approach those values indicated for alluvial sections in regime. Sections initially less than about 800

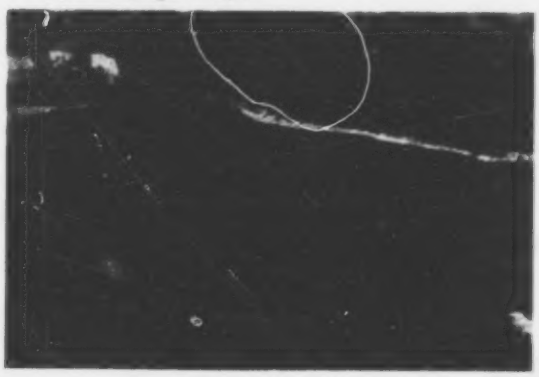
feet in width are expected to adjust to this width. Sections greater than 800 feet wide will probably become depositional sites along the shore, although this process will be very slow. Long term bed erosion is expected in the main body of the channel in all cases, as depths adjust to the value of 22 to 24 feet indicated for alluvial channel sections in the regime.

This channel type included examples of almost all the shoreline types mapped on the Rat-Burntwood Rivers system.

Examination of the various types of channel sections discussed above indicates that adjustments in channel width and depth can be expected in varying amounts for almost all channel sections. Major bed erosion will occur soon after diversion commences. Horizontal recessions can be expected for an extended period of time as width adjustments occur.

In an attempt to estimate the duration of the channel adjustments two river diversions with an extended period of operation were visited. On the Root River Diversion from Lake St. Joseph to Lac Seul, most all alluvial sections appeared to be approaching stability after 15 years of operation. Continuing erosion was observed at the present time, but this was generally localized. Throughout the whole route, slumped banks remain as evidence of increased activity in past years. Flows in this channel were increased from very low flows to a maximum of 6000 cubic feet per second.

On the Ogoki diversion route into Lake Nipigon, an increase in flow from a natural maximum of about 2,000 cfs to a diversion maximum of about 18,000 cfs resulted in channel erosion to bedrock at many sites within the first 15 years (Photograph 101). Continued bank slumping was observed throughout most of the diversion route after 30 years of operation. It must be noted that the visual appearance of banks can be very deceiving. A steep bank devoid of vegetation may appear to be eroding rapidly, yet closer examination and analysis will indicate the longterm rate of recession to be of the order of one inch per year. The effects on vegetation on inspected sites indicated that adjustment processes had slowed considerably, and that at least a measure of stability has been restored. These shorelines would probably be classified as Type 25 (Photograph 102).



PHOTOGRAPH 101 - Typical Ogoki River channel showing slumped banks and erosion.

PHOTOGRAPH 102 - Eroding banks along the Ogoki Diversion, September, 1973.

The time required to return to a stable state is variable depending on the relative increase in flows, the physiographic setting, and bed and bank materials. These two case studies indicated a possible return to stability within 20 years, or possibly a continued unstable state after 30 years. Discharge and material properties along the Burntwood River are considerably different from either case, so the duration of adjustment processes may be significantly different.

A review of publications dealing with erosion rates of cohesive materials indicated a great variability among different materials. The relationship between basic material properties and erosion rates is not well understood.

Critical tractive force, or bed shear stress, for the Burntwood River bank materials has been estimated to be near 0.05 pounds per square foot, (Reference 12). Investigations of similar clays indicated a critical tractive force of 0.066 pounds per square foot for Red River sediments. Critical values calculated for the Red River Floodway ranged from 0.061 to 0.08 pounds per square foot. Based on a review of these investigations, other published works, and bank material properties, a simplified model relating mean traction force and the resulting erosion rate was developed for Burntwood River channels. This equation is given by:

$$E = 26\ (t-0.05)$$

where E is the bed erosion rate in feet per year,
t is the mean tractive force at a given discharge in pounds per square foot.

At a discharge of 35,000 cubic feet per second, Underwood Mclellan and Associates calculated a mean tractive force of 0.10 pounds per square foot for alluvial sections. Substitution in the equation above indicates an initial bed erosion rate in the neighbourhood of one foot per year for alluvial sections. The vertical adjustment required to achieve a regime channel will, therefore, occur in a short time. Corresponding horizontal recession rates are difficult to estimate, but are expected to be between one and five feet per year. Duration of adjustment is anticipated to be between 15 and 50 years at the initial rates.

Considerably higher shear stresses will occur on the Type 2 (bedrock controlled) sections. The effect of bedrock controls on the erosion rate model outlines above is not well understood. Shear stresses for these sections at 35,000 cubic feet per second in the original channel were calculated for the eleven sections. Values ranged from 0.036 to 0.190 pounds per square foot, with a mean of 0.110 pounds per square foot. Vertical erosion rates given by the model would be about 1.5 feet per year. Due to the bedrock control, this would be reduced. If the relative erosion rates are assumed to be affected in the same proportion as the ultimate adjustments in channel dimensions, erosion rates for these sections would be about 2/3 of the corresponding rates for alluvial-controlled sections. Bed erosion rates would, therefore, be about one foot per year.

6.3.3.2 Impacted State Conditions - Footprint Lake: Diversion of the Churchill River flows through the Burntwood River will raise the open water level of Footprint Lake 15 feet (784.5 to 800). Levels are expected to rise an additional 12 feet (800 to 812) under normal ice conditions. Under extreme ice conditions levels may rise an additional distance of eight feet to reach the 820 level.

The horizontal extent of flooding due to a 15 foot vertical rise is as shown in figure 92. At the open water level the impact will be similar to those discussed under low level flooding for "Impact Process Statement for Shorelines", "Inundated Terrain", "River Channels", Section 5.4.1, 5.4.3 and 5.4.4. Section 6.3.3.1 deals specifically with the impact anticipated under winter ice surcharge conditions.

Raising of the water level to the 800 foot elevation will change the main part of Footpring Lake community into an island and inundate sections of the road leading from the community to P.R. 391.

In general, flooding along the bedrock control Shoreline Type 11, 13 and 15 will remain contained within the backshore typical of that shoreline. Overburden will erode until bedrock is reached along the majority of the type 13 and 15 shorelines. Extensive slumping can be anticipated along shorelines characterized by thick clay overburdens. Such shorelines may not achieve stability for a prolonged period of time. The bedrock shorelines that do achieve stability however may not be aesthetically pleasing or be of a recreation value due to the undercut trees along the shoreline and slumping clay banks in the backshore area.

Flooding will in all cases be greater horizontally along Type 14 shoreline than either type 13 or 15. In this case, the embayments will remain congested with dead standing trees.

Types 23, 24 and 28 will be flooded beyond their immediate backshore areas. It is these areas that will contain the greatest amount of debris, both standing and floating and will take the longest to achieve a natural appearance.

The beaches and marshes in the area will be inundated and likely not redevelop to the extent they were in the natural state within a 50 year period.

Overall the shoreline impact will not be as severe along the lake north of Footprint Lake due to the high occurrence of steep bedrock shorelines.

Horizontal flooding will be greatest along the Footprint River and tributaries. These shorelines will likely not stabilize as quickly as those in the adjoining lakes.

The effects of a raised water level on the shoreline at Nelson House has been covered in another study (Reference 19).

6.3.4 SUMMARY STATEMENT - NOTIGI TO SPLIT LAKE: The waterway from Notigi to Split Lake includes portions of the Rat and Burntwood River and adjoining lakes: Wapisu, Threepoint Lake, Wuskwatim, Opegano, Birch Tree and Apussigamasi. Major lakes draining into the system that will be affected are: Footprint Lake at Threepoint Lake, Ospwagan Lake at Manasan Falls and Mystery Lake upstream of Apussigamasi. The Odei River joins the Burntwood River approximately eight miles upstream of Split Lake.

The Rat and Burntwood Rivers flow through glacial Lake Agassiz deposits. Consequently, the majority of the shorelines and backshore areas exhibit silts and clays overlying bedrock. In general, irregular and narrow channel sections exhibit bedrock control shorelines while channel widenings and embayments are characterized by silt and/or clay shorelines. Althought the majority of the clay bank shorelines have stabilized, others are actively eroding. Numerous scenic falls and rapids are located along the system.

All lakes along the system are characterized by a deep clay overburden above the water washed zone, a feature absent within the lakes along the Upper Rat River. Wapisu and Wuskwatim contain similar shoreline types - primarily bedrock with sandy beach embayments. Threepoint Lake is characterized by low shorelines, marshes and extensive beaches. Opegano and Birch Tree Lakes are located in deep lacustrine deposits. Consequently, the eroding shoreline of the latter two lakes are backed by steep slumping clay banks. Apussigamasi Lake shorelines are stable, consisting of an alternating series of clay and bedrock.

After the diversion of the Lower Churchill River waters and regulation at the Notigi control structure, the mean discharges along the Burntwood River will be increased by nine to ten fold. For example, mean discharges will be increased from 3,100 cfs to 31,200 cfs at Wuskwatim Lake and from 3,640 cfs to 31,700 cfs at First Rapids. Under mean regulated water level conditions, Wapisu Lake will be raised some 16 feet while Apussigamasi Lake will be raised some 8 feet.

The impact on the bedrock shorelines of the lakes between Notigi to Split Lake will be one of erosion until bedrock is reached. However, once stabilized, these shorelines will still have undercut trees and driftwood cluttering up the shoreline. Protected shorelines will take the longest to achieve a natural state; they will remain congested with dead standing and fallen trees.

Sand beaches and marshes will be inundated and not be redeveloped to the extent they were in the natural state. Steep clay banks will continue to erode, although at an accellerated rate. These shorelines will likely appear much as they did in the natural state. Abnormal slumping will be evident where permafrosted materials are thawing. Steep bedrock shorelines will not be significantly altered.

The impact processes along the river channel will be accelerated due to the influence of flowing water and moving ice on vegetation and materials. In general, an increase in discharges will bring about an increase in channel size, both vertically and laterally.

Each shoreline type will be affected differently. Little change will occur where bedrock controls the channel width but clay shores may recede approximately 60 to 70 feet on either side. Bedrock shorelines are expected to achieve stability within 30 years while the clay shorelines may actively erode indefinitely as is the case in the natural state.

Flooding will be greatest horizontally along the tributaries. These areas will remain cluttered with dead standing trees for a longer period than the river banks. In general, the rivershores will not contain the amount of standing and fallen trees typical of the lakeshore. The increased water levels will also inundate the silt bars and subsequent marsh zones along the rivershore and tributary mouths. The re-establishment of these marsh zones are largely dependent upon the deposition of materials in the new water-washed zone.

An additional impact along the diversion route will be produced by the winter ice regime. High discharges during the winter, combined with the formation of an ice cover on the channel, are expected to result in winter water levels being about ten feet higher than the maximum summer levels. As an annual phenomena, the effect of the winter ice surcharge will be one of tree mortality and removal in the winter flood zone. Consequently, within twenty years, these zones will only support herbaceous vegetation, primarily sedges and grasses, similar to ice scour zones along the Lower Churchill and Nelson Rivers.

6.4 THE CHURCHILL RIVER

The Churchill River traverses the north of the three Prairie Provinces rising with Beaver Creek in Alberta, accepting the flow of several tributaries in Saskatchewan and Manitoba and finally spilling into Hudson Bay at the present-day port of Churchill. It drains an area of 115,000 square miles, 38,000 of which is in Manitoba, and has an average flow at its outlet in the order of 40,000 cfs. Its flow is increased in Manitoba by about 50 percent.

Characteristic of most of its length, certainly in the shield, is the pool and rapid sequence of the Churchill River. Wide lake expanses connected with channels containing several rapids and falls dominate the upper 80 percent of the river. In the remaining sections the drop in elevation is no longer concentrated at falls. The water is generally fast, rapids are frequent but they are less vigorous than those on the upper reaches. Most commonly, bedrock controls the river both vertically and horizontally, however, in the lower portions the control is exhibited generally just in the vertical.

The underlying geology in Alberta, Saskatchewan and part of Manitoba is Precambrian in origin. Beginning about 90 miles upstream of the Bay, the river flows over Paleozoic Limestones before slipping over a ridge of Precambrian Sandstones into Hudson Bay.

The bedrock is concealed by an overburden varying in depth up to 150 feet. Above Island Falls, the material is a glacial till relatively shallow in depth. Between Island Falls and Missi Falls, the rivers and lakes have cut through several feet of Lake Agassiz sediments. High promontories lack this cover but generally speaking these deposits obscure the irregular bedrock topography. Below Missi Falls glacial till again predominates. This till gradually increases in depth to over 100 feet at a point some 60 miles upstream of the Bay. This point marks the boundary of the former Tyrrell Sea, and between here and the Bay the overburden is of marine origin. It decreases in thickness closer to Hudson Bay.

The variety of landscapes provided by the river and its banks certainly makes it one of the most beautiful rivers in Manitoba. It is the only large river in the Province, at this point in time, that is still untouched, a fact which must further enhance its value.

For the purposes of our study the Churchill River in Manitoba has been divided at Missi Falls into the Upper Lakes segment and the Lower Churchill.

6.4.1 NATURAL STATE CONDITIONS - LEAF RAPIDS TO MISSI FALLS: The Upper Lake segment (Leaf Rapids to Missi Falls) includes a portion of the Churchill River, Opachuana Lake and Southern Indian Lake. Together these bodies of water consist of 1,812 miles of shoreline encompassing in total of some 763 square miles of water surface.

Southern Indian Lake, the largest, is fed at its south-west arm by the Churchill River via Opachuana Lake and numerous other smaller water ways, the Barrington, Muskwesi and Waddie Rivers. Out-flow from the lake is through the Churchill River via two channels, Missi Falls and Missi Rapids at the northeast portion of the lake.

The area overall displays rolling to undulating relief identified with the Canadian Shield. Relief in general is low with local minor variations. The local erratics, glacial striae, eskers and drumlinoid features are evidence of the south westerly direction of travel of the last advancing glaciers. As a consequence of this pleistocene activity, the overburden may be either lacustrine clay, till, or glacio-fluvial. Exposed bedrock can only be found in areas of moderate relief. Organic overburden has only recently accumulated in the poorly drained areas. Although the soil types vary considerably over each region, the largest percentage of the area is covered with lacustrine clay of varying thicknesses. The presence of varved clay substantiates the fact that a portion of glacial Lake Agassiz extended into the Southern Indian and Opachuanau Lake area.

The entire study area lies within the Northern transition zone of the Boreal forest. Plant communities present are a direct reflection of the soil materials, local drainage, and past disturbances. The treed muskeg community is associated with low poorly drained areas while jack pine, white spruce and poplars are identified with the higher well drained sites. Black spruce is the predominant tree cover. The wet land communities consisting of a variety of hydrophytes are well developed along the numerous ponds, lakes and water ways of the shield.

The lake and channel consist of a wide variety of shoreline characteristics controlled by the local topography, relief, overburden materials and exposure. Areas exhibiting similar shoreline types were grouped into reaches to facilitate the discussion on the area and to enhance the readers understanding of the particular reach. The significance of this area breakdown is evident in Table 34.

In general the upper portion of Southern Indian Lake is identified by the low relief, clay overburden and occurrence of granular material. Consequently this portion of Southern Indian Lake contains the greatest percentage of the Fen (Type 31), Low Willow (Type 28), Low Alluvial (Type 24), Treed Muskeg (Type 26), and Coarse Grained Material (Type 22) shorelines.

The Southern reaches are characterized by the high occurrence of bedrock control shorelines, Steep Bedrock (Type 11) shorelines in particular become increasingly predominant. The proportion of Low Bedrock (Type 13), Bedrock Control with Overburden Beach (Type 14) and Low Bedrock Controlled Shoreline (Type 15) varies in any one reach along with smaller representations of other shoreline types. The South Bay area is readily identified from the other local reaches by the occurrence of the thick lacustrine overburden. It is of particular interest to note the marked absence of Type 12, 21 and 25 shorelines all of which are typical of the Lower Nelson and Churchill River system. Each of the following nine reaches will be discussed separately.

TABLE 34

SOUTHERN INDIAN LAKE - OPACHUANAU AND LEAF RAPIDS MILEAGES OF SHORELINE TYPES

CLASSIFICATION

Reach	11	11M	12	13	13M	14	14B	14M	14BM	15	15B	15M	15BM	21	22	22M	23	24	24M	25	26	26B	26M	27	27M	28	28M	31	TOTALS
Moss Lake Reach 1				9.8	2.3	1.6	0.3	4.2	2.6	1.1		2.7			0.6			28.9	2.7		0.5			0.8	1.8	0.2		4.3	64.4
Waddie River Reach 1				1.0		2.0				2.3		0.8			9.5	1.4		6.2			10.1	0.4		0.8	0.5	3.5		1.8	40.3
Hammond Point Reach 1				25.0		7.2	4.9	110.0	4.2	31.1	0.2	2.2			11.5	2.7	0.1	5.1	4.1					0.1		0.9	2.6	0.6	112.5
Missi Falls Reach 2	5.9			117.1		17.6	5.6	10.1	0.9	29.8					5.3	1.7		3.1	2.0		1.3					0.3			204.5
Long Point Reach 3	32.0			197.0		8.2	4.7	2.3	0.1	29.8	1.5				4.3			12.8	0.5		0.5			0.7		1.3	0.5		298.4
Mulcahy Lake Reach 4	132.4	8.2		52.3	11.5	6.5	1.0	6.9	0.1	0.5					0.2		1.2	3.7	6.9							0.1	0.1	0.8	232.4
Lemay Island Reach 5	31.7			283.8		0.2	17.0	11.5	11.1	16.2								1.6	0.6										373.7
S.I.L. Community Reach 6	24.8			119.9		17.2	5.1	11.9	0.2	26.8					10.1		1.9	5.1	0.6		0.9		0.1	3.7				0.6	228.9
South Bay Reach 7	4.6			26.8		19.8	4.6	9.4	0.4	8.0	4.5	2.4	1.6					0.5	1.8		1.5	2.4	1.6	0.4		0.5			92.9
Opachuana Reach 8	9.2			73.2	1.4	2.8	1.3	2.0	0.6	2.7		0.3			2.3	0.2	0.6	2.4	0.1		0.1					0.2	0.2	1.9	101.5
Leaf Rapids Reach 9	9.0			31.8	2.0	3.7	0.5	2.8	0.1	5.4		2.1			0.9			3.0	0.8					0.4		0.2	1.6	0.3	64.6
TOTALS	249.6	8.2		937.7	17.2	86.8	45.0	71.1	20.5	153.7	6.2	10.5	1.6		44.7	8.0	1.8	72.4	20.1		16.9	2.8	1.7	7.0	2.3	9.2	5.0	10.2	1812.2

NATURAL STATE OF EXISTING SHORELINES: Reach I - Moss Lake, Hammond Point, Waddie River: Reach I occupies the extreme northern portion of Southern Indian Lake (Figure 108). The Reach is broken down into three main sections according to shoreline characteristics, the Moss Lake Region, the Central Region or Hammond Point and the Waddie River Region. These regions contain 64, 112 and 40 miles of shoreline respectively. Site location of the included profiles and photographs are as shown in Figure 108.

Moss Lake is characterized by extensive offshore marshes, particularily along the western shore while the eastern shore consists of alternating bedrock headlands and sandy embayments. Type 22 shorelines are replaced by Type 27 shorelines along the north-eastern portion of the lake-shore. The area directly south-east of Moss Lake consists of a complicated series of long floating fens (Type 31), offshore marshes, lowlying sandy shorelines (Type 27), and low alluvial shorelines (Type 24). Very little bed-rock is exposed here, but promontories are still controlled by bedrock in structure (Type 15). The Muskwesi River is mainly a Type 24 shoreline. The milages of significant shoreline types are as follows: Type 13-12 miles, Type 14-9 miles, Type 15-4 miles, Type 24-31 miles, Type 27-3 miles and Type 31-4 miles.

The central region containing Hammond Point and the Northern portion of Moose Point differs from Moss Lake and Wadie River regions due to the alternating series of bedrock control and coarse material shorelines. The south-eastern portion of this region falls within the esker-kame complex that stretches from Waddie Lake in a south-westerly direction down into Moose Point. This complex continues on into Sand Island and Bear Narrows of Reach Two. The sweeping wide sand beaches of this region are typically backed with a ridge of sand in the backshore area (Figure 105). There are 14 miles of Type 22 shoreline.

Most headlands are Type 13 (25 miles) while a large proportion of Type 14 shorelines (26 miles) are characterized by a beach and/or marsh formation (Photograph 103, Figure 106). Type 13 shorelines are characterized by the occurrence of boulders in the water-washed zone (Photograph 104, Figure 107). Type 15 occupies some 34 miles of shoreline.

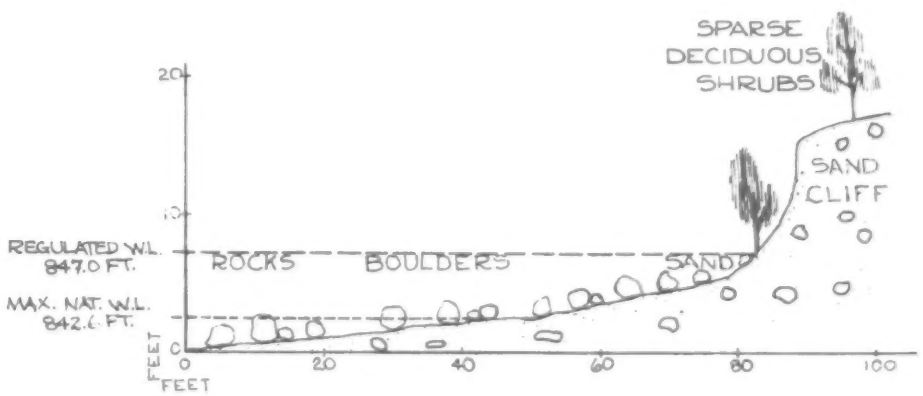
The Hammond Point sector differs in that the headlands are mainly Type 15 while the embayments are Type 14 rather than Type 22. North of Hammond Point Types 24 and 28 shorelines become in-creasingly important. The area contains nine miles of Type 24 and three miles of Type 28 shoreline. All other shoreline types occur in smaller amounts.

Waddie Lake is characterized by a local esker complex, consequently a significant proportion of the shoreline is Type 22 (11 miles). The relocation of coarse grained materials has resulted in the formation of short stretches of Type 27 shoreline (one mile). The low relief of the general area is the prime reason for the extensive stretches of Type 26 shoreline (ten miles), contributing to the highest proportion of treed muskeg shoreline of all nine reaches.

Exposed bedrock is almost non-existant, although promontories are still bed-rock controlled in structure. Type 13, 14 and 15 constitute some one, two and three miles respectively.

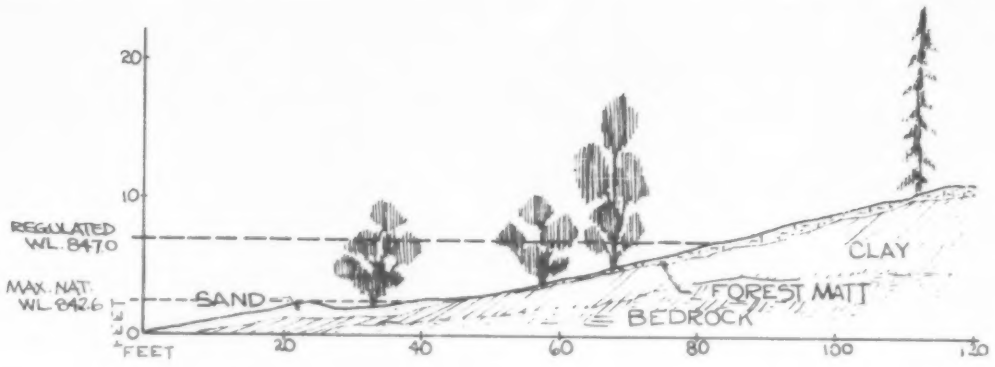
The character of the Waddie River shoreline is determined by the lacustrine clay overburden. The six miles of Type 24 shoreline are occasionally broken with bedrock control stretches. The outlet of the Waddie River consists of an extensive fen complex that extends out into the lake area. This entire region consists of four miles of Type 28 shoreline and two miles of Type 31 shoreline.

PHOTOGRAPH 103 - Reach 1, Site 2. An extensive sand overburden (Type 14b) shoreline.



PROFILE OF A KAME HILL (TYPE 22) SHORELINE. REACH 1, SITE 3.

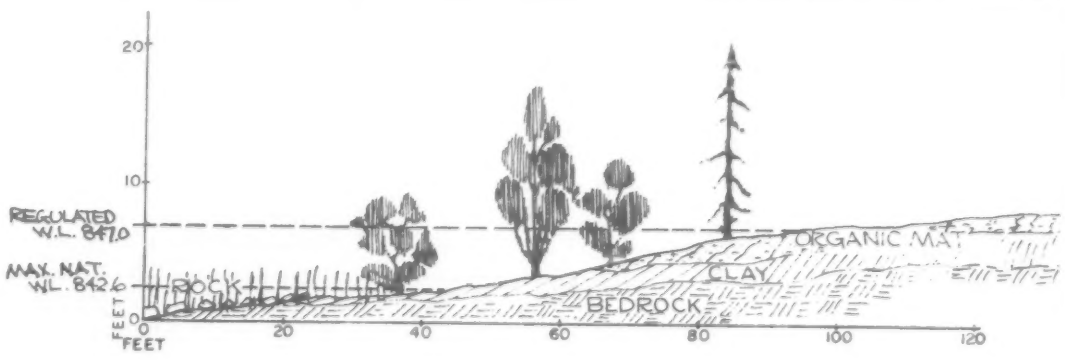
FIGURE 105



PROFILE OF A SAND OVERBURDEN (TYPE 14b) SHORELINE. REACH 1, SITE 2.

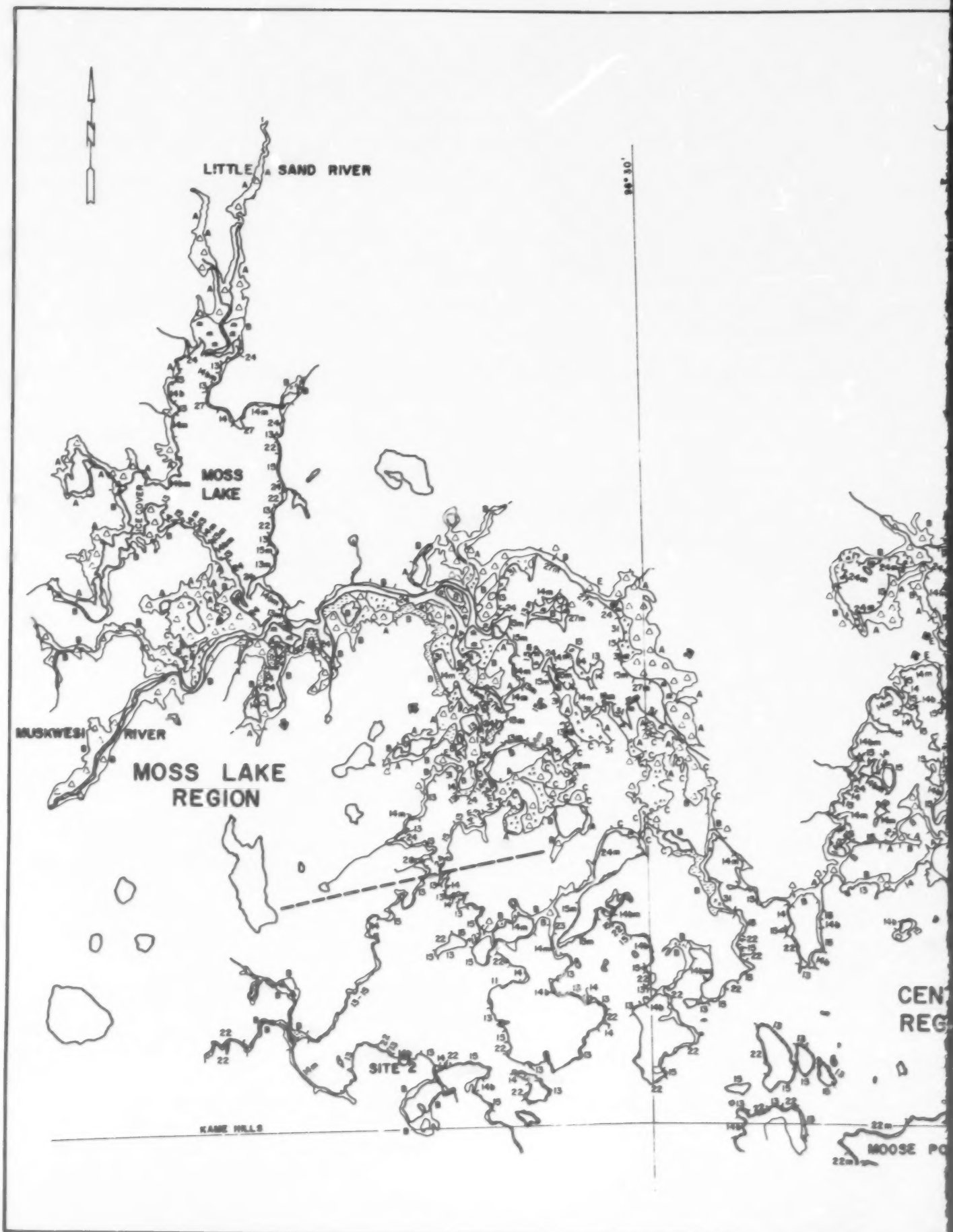
FIGURE 106

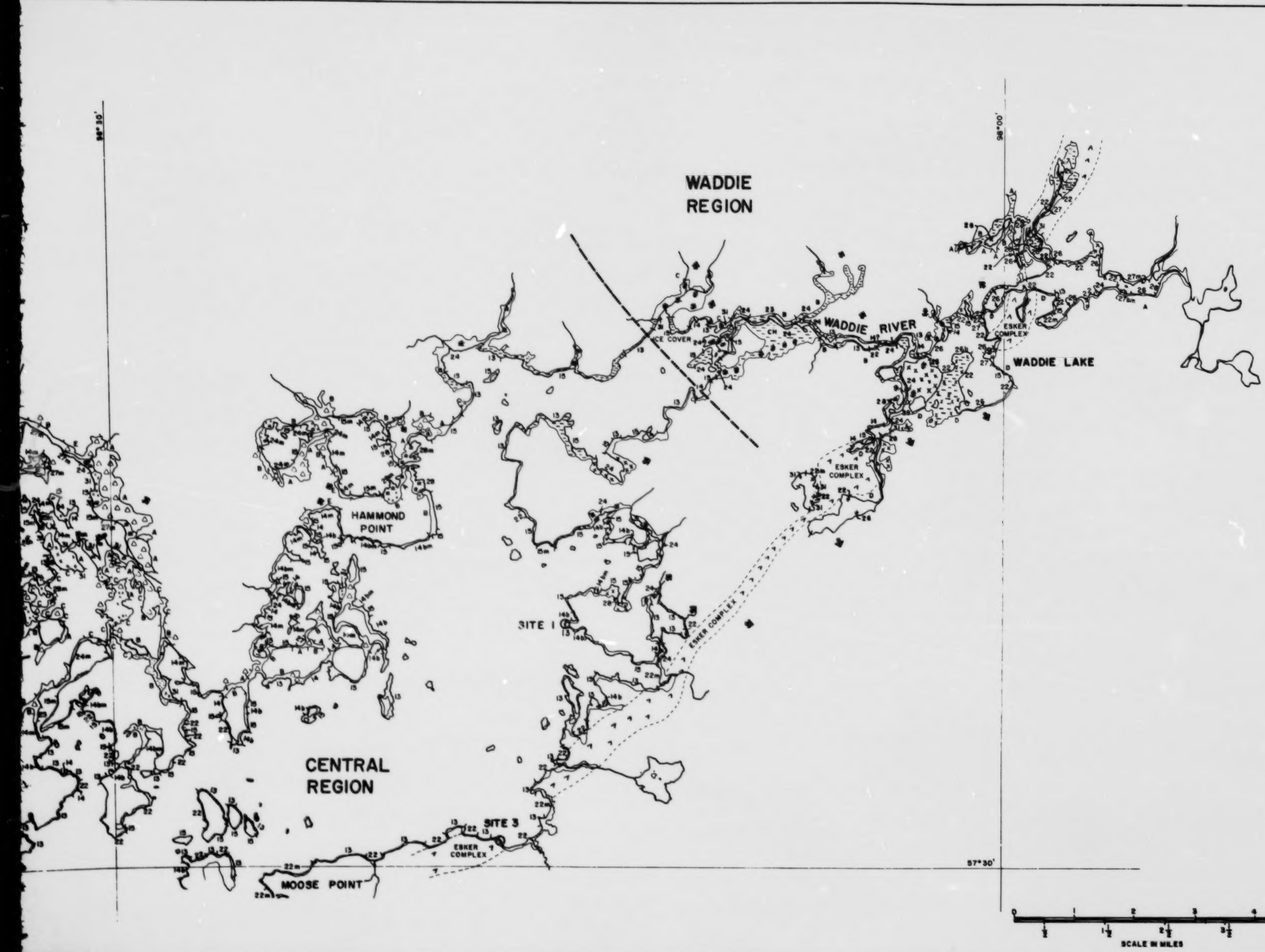
PHOTOGRAPH 104 - Reach I, Site 1. A low bedrock promontory (Type 13) shoreline.

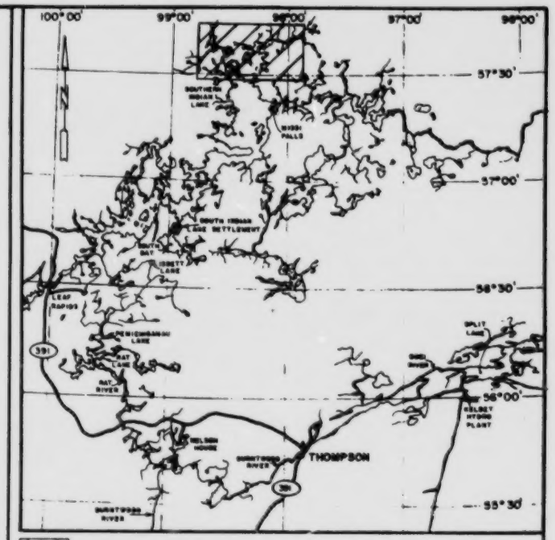


PROFILE OF A LOW BEDROCK SHORELINE. REACH 1, SITE 1.

FIGURE 107


LITTLE SAND RIVER
MOSS LAKE
ICE COVER
MUSKWESI RIVER
MOSS LAKE REGION
SITE 2
KAME HILLS
MOOSE PO





LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
X x X x	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 108

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH I
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED	RECOMMENDED
D.S.	R.P. N.S.	T. M.	DATE	

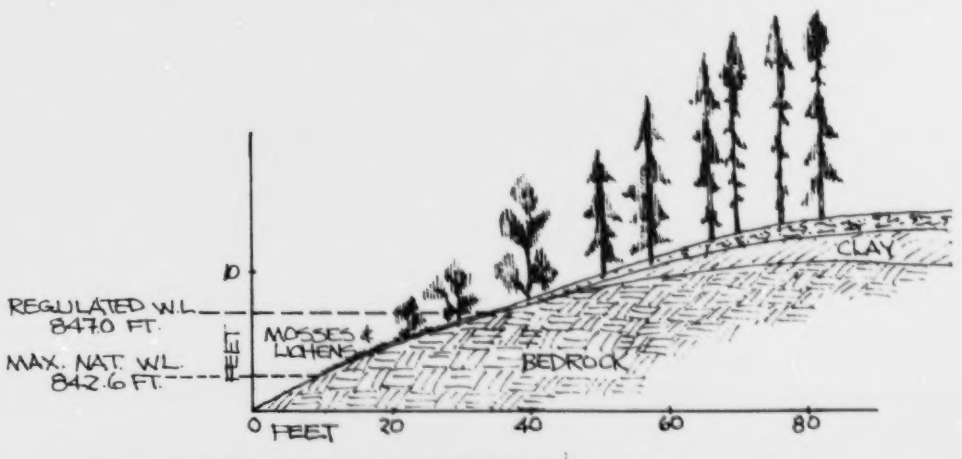
SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	24 of 58	61-1-1025

Reach 2 - Missi Falls: This reach lies within the immediate area of Missi Falls and encompases both Moose Point and Loon Narrows (Figure 111). Site locations of the included profiles and Photographs are as shown in Figure 111. Reach 2 contains some 203 miles of shoreline. The greatest portion of this reach is one of an alternating series of Type 13B, 14 and 15 shoreline, each one consisting of 117, 34 and 30 miles respectively. The overall relief increases as indicated by the occurrence of Type 11 shoreline (6 miles) and a reduced occurrence of Type 26 shoreline (one mile). Due to the slope, the width of the water-washed zone of Type 11 is less than that of Type 13 (Photograph 105, Figure 109).

In this reach the type 14b shorelines may consist of a clay overburden or boulder beach (Photograph 106 and Figure 110). The northern portion of the reach from Moose Point to Bear Narrows is typified by the long, wide, sweeping Type 22 shorelines. These nine miles of shoreline are still part of the esker-kame complex running south-west from Waddie Lake.

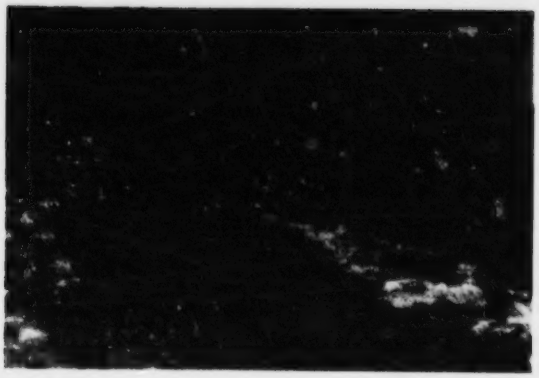
The five miles of Type 24 shoreline are restricted to localized embayments. Other shorelines types occur in less significant amounts.

PHOTOGRAPH 105 - Reach 2, Site 4. Steep bedrock shoreline (Type 11).

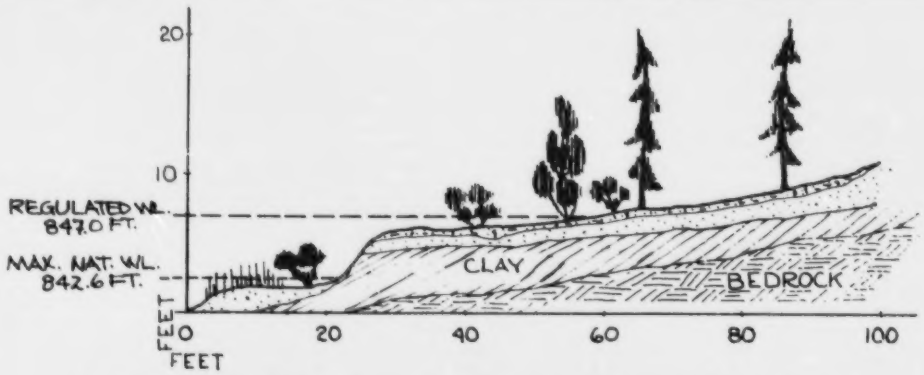


PROFILE OF STEEP BEDROCK SHORELINE (TYPE 11), REACH 2, SITE 4.

FIGURE 109



PHOTOGRAPH 106 - Reach 2, Site 5. A boulder and sand (Type 14b) shoreline.



PROFILE OF A SAND AND BOULDER (TYPE 146) SHORELINE, REACH 2, SITE 5

FIGURE 110

Reach 3 - Long Point: Reach 3 the Long Point area, (Figure 112) encompasses 298 miles of shoreline. Long Point varies from the previous reaches due to the higher occurrence of Type 11 shoreline (32 miles) and the pronounced depth of overburden. Lacustrine clay deposits typically occupy the backshore areas of the bedrock control shoreline. In this reach there are 197 miles of Type 13B, 16 miles of Type 14 and 31 miles of Type 15 shoreline.

The north eastern portion of the reach is predominantly bedrock control. Along the upper portion, the offshore area consists of a variety of materials including boulders, gravel and sand. Further south, the offshore consists primarily of a bare rock shelf covered with boulders. Where fine materials were present, marshes occured but this is not common. The beaches average ten feet in width. They rise gradually from the water line to form a silty clay bank.

The north-western portion of the reach is primarily bedrock control with the occasional granular shoreline.

Long Point consists of an alternating series of bedrock headlands, embayments and frequent Type 28 shorelines. This reach contains in total some four miles of Type 28. South of Long Point, Type 11 and 22 shorelines increase in predominance. In total there are four miles of Type 22 shoreline. On Long Point, Type 22 is characterized by sand hills in the backshore areas (Photograph 107). These deposits are the main source of materials deposited along bedrock embayments (Photograph 108).

The thirteen miles of Type 24 shoreline are contained primarily within the southwest portion of the reach (Photograph 109).

A considerable amount of the backshore areas consists of treed muskeg. Permafrosted mineral soil was evident below the peat layer on many of the sites.

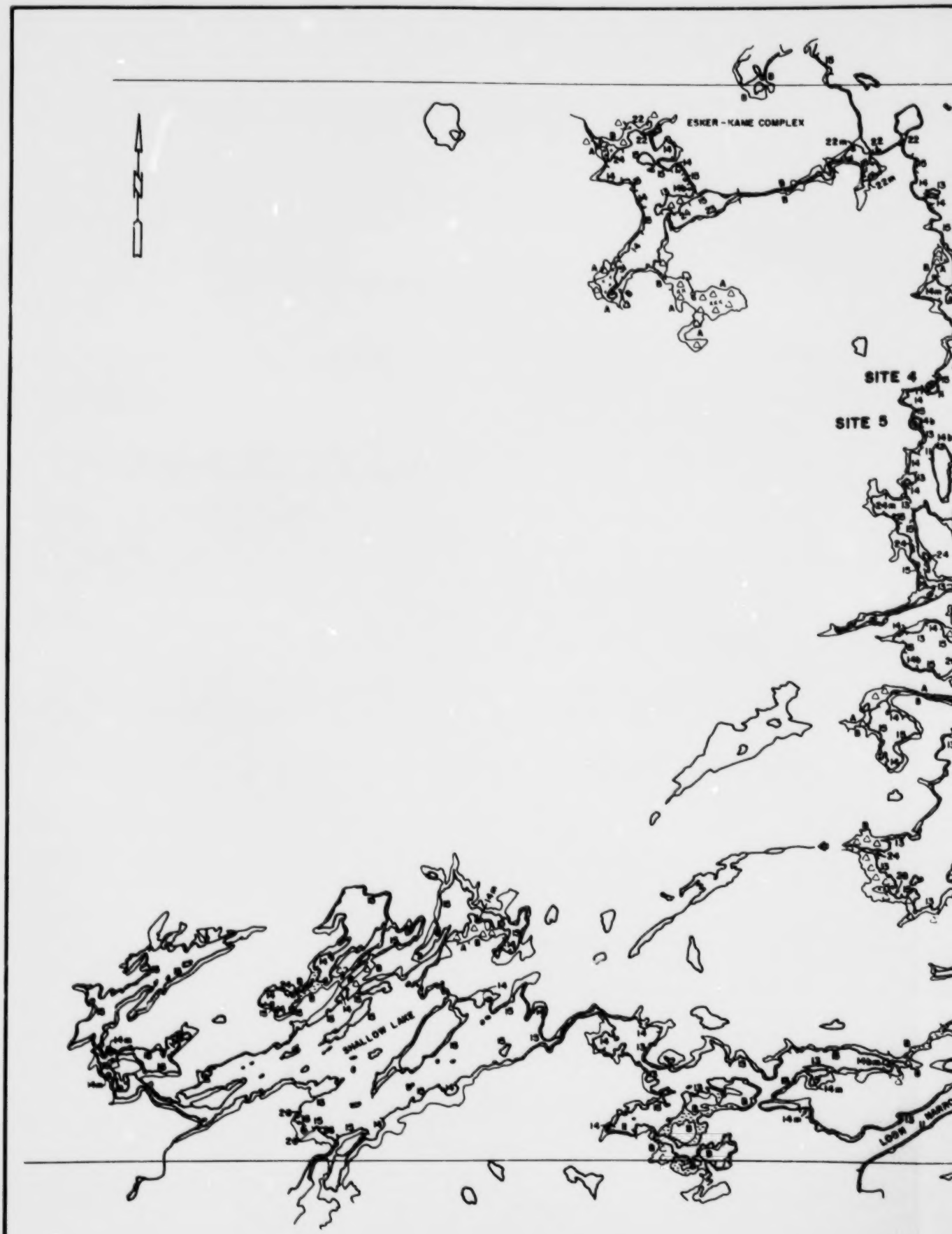
PHOTOGRAPH 107 - Reach 3, Site 9. A sandy (Type 22) shoreline at Long Point.

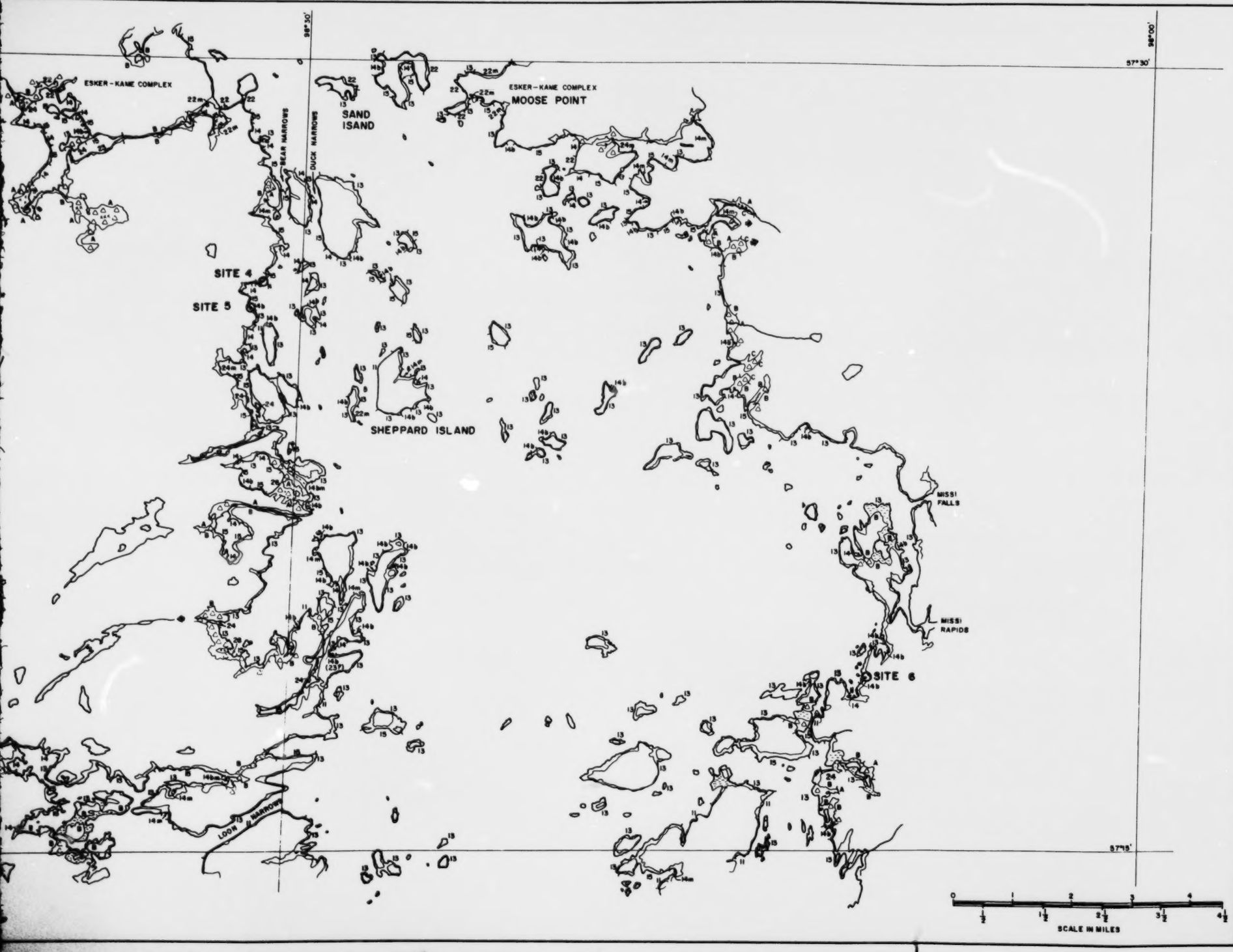
PHOTOGRAPH 108 - Reach 3, Site 7. A well formed sand beach (Type 14b) shoreline at Long Point. Thawing permafrost is the source of water intersecting the sand beaches.

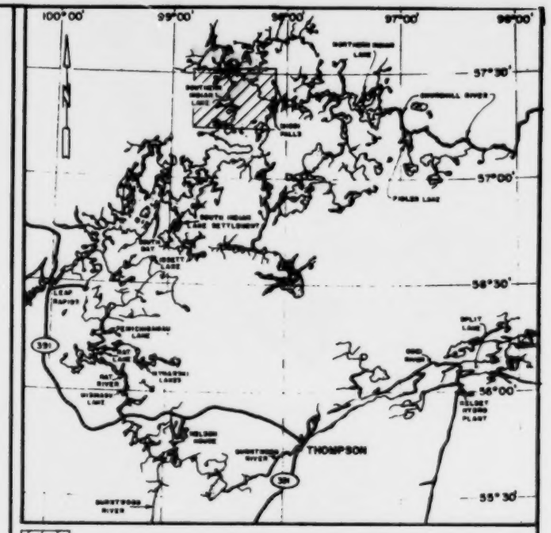
PHOTOGRAPH 109 - Reach 3, Site 8. A Low Alluvial Shoreline (Type 24) typical of the slow flowing streams of South Indian Lake.

Reach 4 - Mulcahy Lake: The Mulcahy Lake reach (Figure 113) is situated west of Long Point, lying between Pine and Grandmother Lakes. Basically the reach consists of a series of channels and a number of lakes dotted with islands. Type 11 constitutes 141 miles of the 232 miles of shoreline. This reach contains the highest proportion of steep bedrock shoreline of all nine reaches. The remainder of the shoreline is primarily Type 13 (64 miles) and Type 14 (15 miles). These bedrock shorelines alternate with steep bedrock shorelines throughout the entire reach.

The only low lying shoreline of any significance is Type 24 (11 miles) which is confined to the numerous embayments. All other shoreline types are of infrequent occurrence.


N
ESKER - KAME COMPLEX
SITE 4
SITE 5
SHALLOW LAKE





LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. III

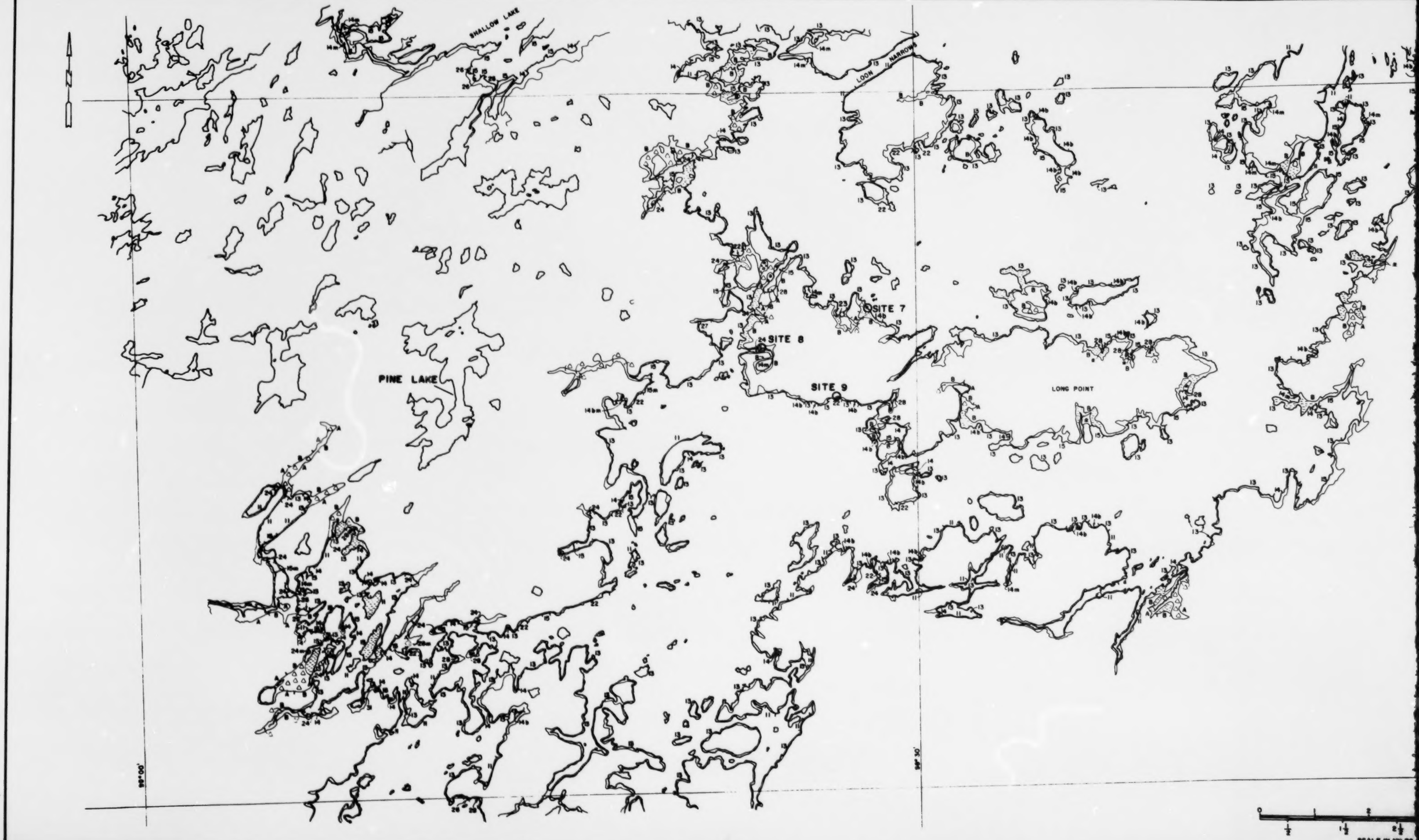
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

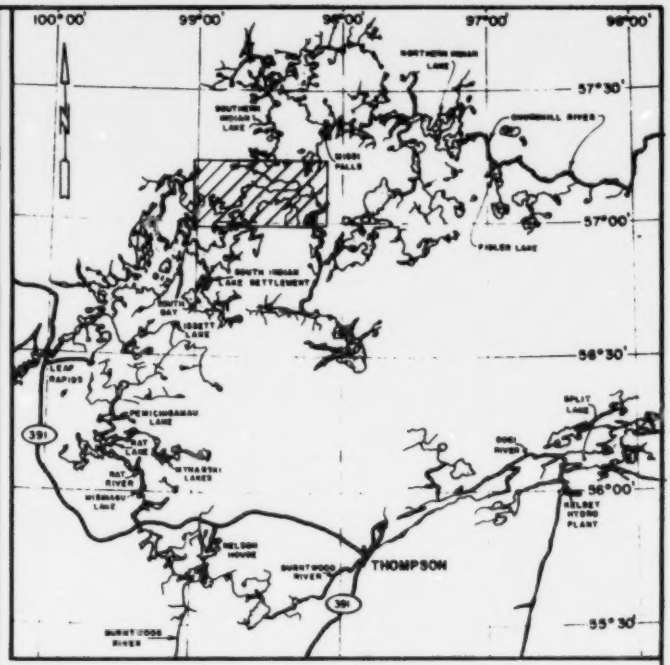
CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 2
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED
D.S.	M.S.	T.M.	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	25 of 88	61-1-1088


SHALLOW LAKE
LOON
NARROWS
PINE LAKE
SITE 7
SITE 8
SITE 9
LONG POINT
95° 00'
94° 00'
0
1/2
1
1 1/2
2
2 1/2
SCALE IN MILES



▨ = LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
X x X x	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 112

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 3
SHORELINE AND INUNDATED AREA CLASSIFICATION

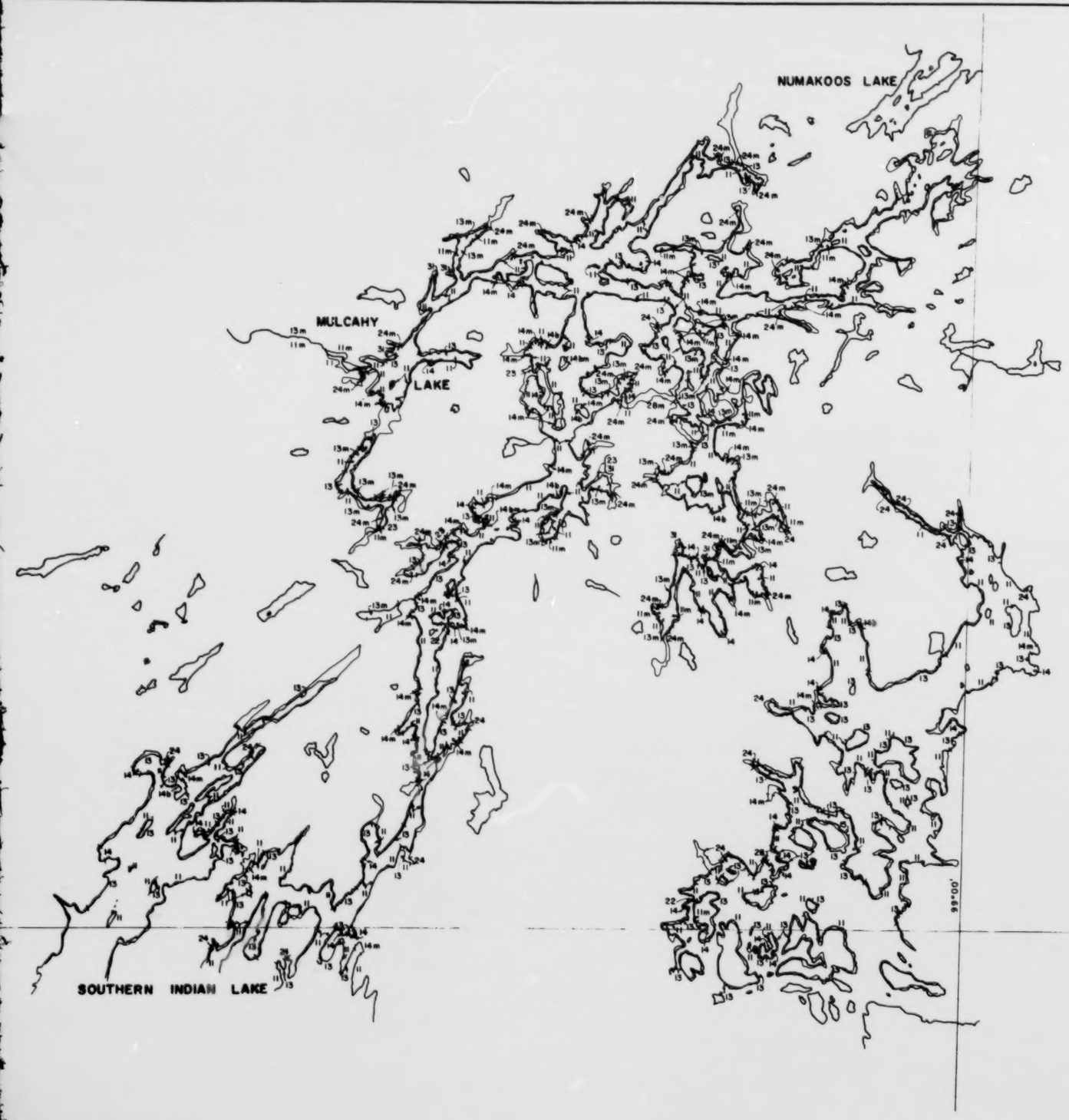
PREPARED	DRAWN	CHECKED	SUBMITTED DATE	APP'D DATE
D.S.	N.S.	T.M.		

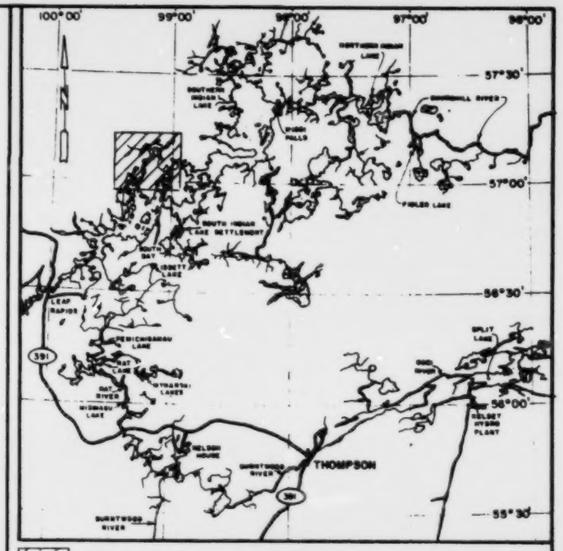
SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	28 OF 58	61-1-1025

N

MUL

SOUTHERN INDIAN LAKE





= LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

0 ½ 1 1½ 2 2½ 3 3½ 4 4½
SCALE IN MILES

FIG. 113

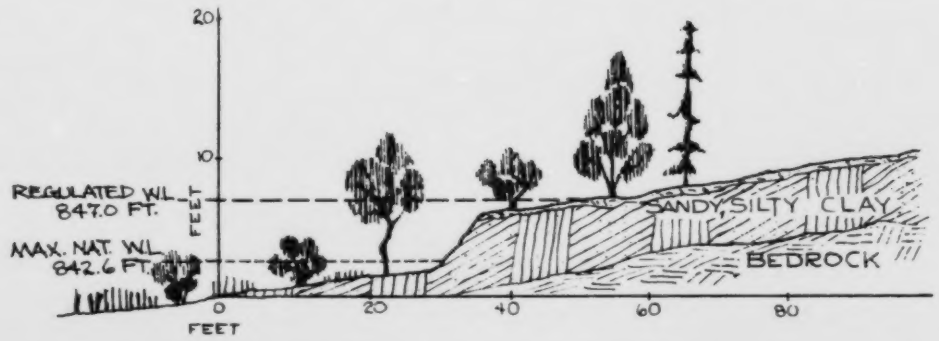
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 4
SHORELINE AND INUNDATED AREA CLASSIFICATION

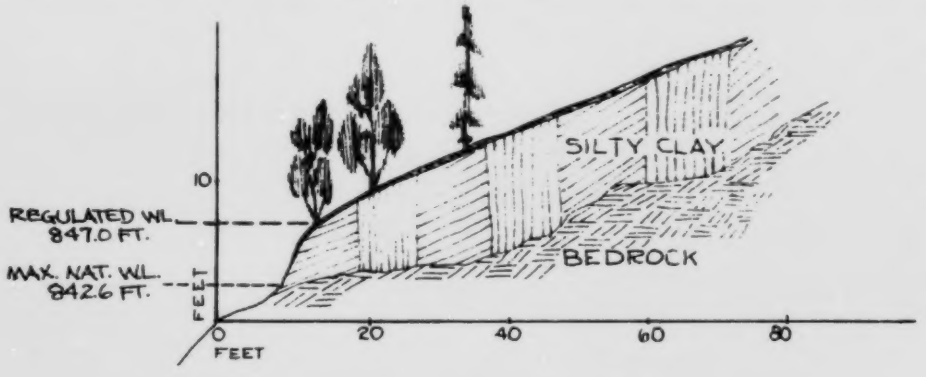
PREPARED	DRAWN	CHECKED	SUBMITTED DATE	APPROVED DATE
D.S.	N.S.	T.M.		
SCALE AS SHOWN	DATE APRIL/74	SHEET NO. 27 of 58	FILE NO. 61-1-1025	

Reach 5 - Lemay Island: Lemay Island Area consisting of 374 miles of shoreline is the largest reach in Southern Indian Lake (Figure 116). Site locations of the included profile are as shown in Figure 116. The high mileage is due to the maize of islands found within the reach. Most shorelines are bedrock controlled. The lakeshore is comprised of an alternating series of Type 11, 13B, 14 and 15, each represented by 32, 284, 40 and 16 miles of shoreline respectively. The majority of Type 14 shorelines are characterized by beach and/or marsh formations (Figure 114). The depth of overburden in the area is particularly evident along Type 15 shorelines (Figure 115). The absence of granular and low lying shorelines distinguishes this reach from the previously discussed ones.



PROFILE OF A BEDROCK CONTROLLED OVERBURDEN BEACH SHORELINE (TYPE 14), SITE 11.

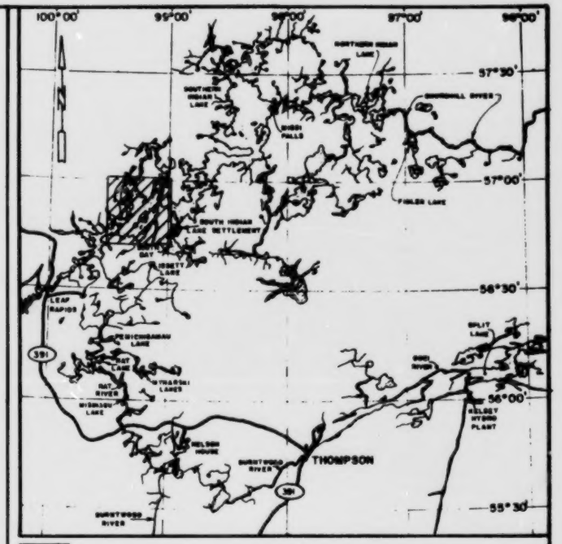
FIGURE 114



PROFILE OF SITE 10, REACH 5 OF FIGURE 116, A BEDROCK SHORELINE (TYPE 15).

FIGURE 115

57°00'
SITE 11
SITE 10
54°30'



▨ = LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
✱ ✱	SEDGE COMMUNITIES
X x X x	TREED MUSKEG TERRAIN
△▽ △▽	TREED MUSKEG TERRAIN WITH PERMAFROST
• • •	GLACIAL DRIFT TERRAIN
• • •	BEDROCK OUTCROPS
= = =	CLAY OVERBURDEN
➧	FLOODING POSSIBLY GREATER THAN INDICATED

0 ½ 1 1½ 2 2½ 3 3½ 4 4½
SCALE IN MILES

FIG. 116

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 5
SHORELINE AND INUNDATED AREA CLASSIFICATION

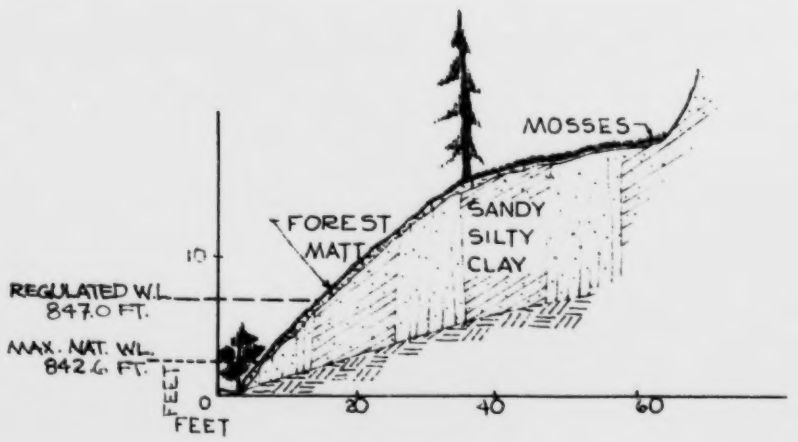
PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
D.S.	R.P. & M.S.	T. M.	DATE 7 Mar. 74	DATE
SCALE AS SHOWN	DATE APRIL/74	DRWG. NO. 26 of 58	FILE NO. 61-1-1085	

Reach 6 - South Indian Lake Community: This area of southern Indian Lake includes Sandhill Bay to the north and the community the south (Figure 118). The site location of the profile is as shown in Figure 118. The reach includes 229 miles of lakeshore. The shoreline types present are similar to those of Long Point, Reach 3.

The Sandhill Bay area differs from the rest of the reach due to the high occurrence of Type 22 shoreline (10 miles). The granular overburden forms high ridges along the bay with broad well formed beaches extending out from the toe of the deposit. The beach itself often consists of a thin sand veneer overlying the lacustrine clay. The area differs from the typical Type 22 shoreline in that the base of the ridge is commonly littered with boulders and the offshore area supports marsh vegetation. The typical exposed face of the ridge is colonized by deciduous shrub and trees while the top of the bank itself supports jack pine. There are some 4 miles of Type 27 shoreline found in conjunction with the Type 22 shoreline.

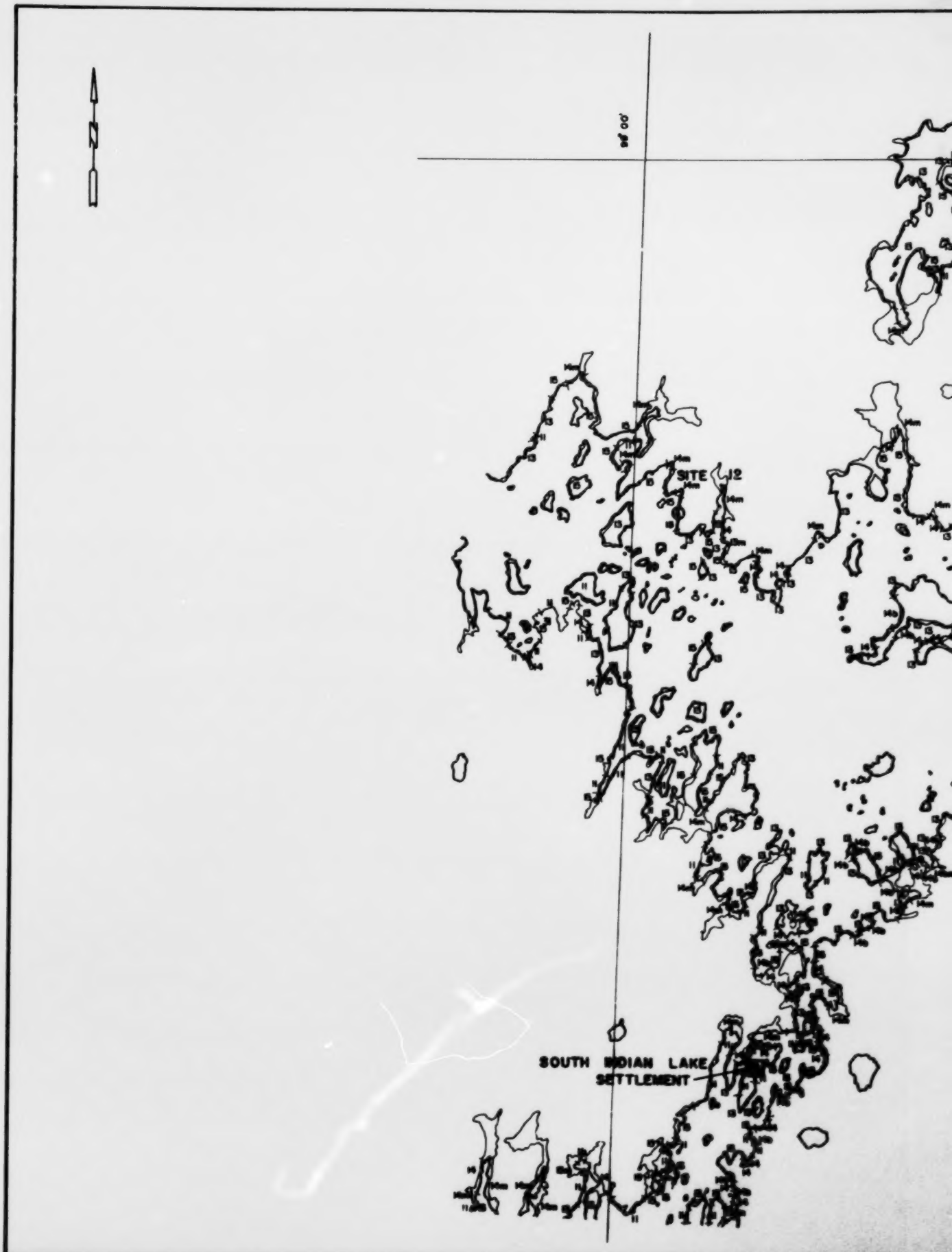
The remainder of the lake is typically one of bedrock control, the predominant type being Type 13B (120 miles) with 34 miles of Type 14, 27 miles of Type 15 and 25 miles of Type 11. The overburden is relatively thick in some areas as shown in Figure 117.

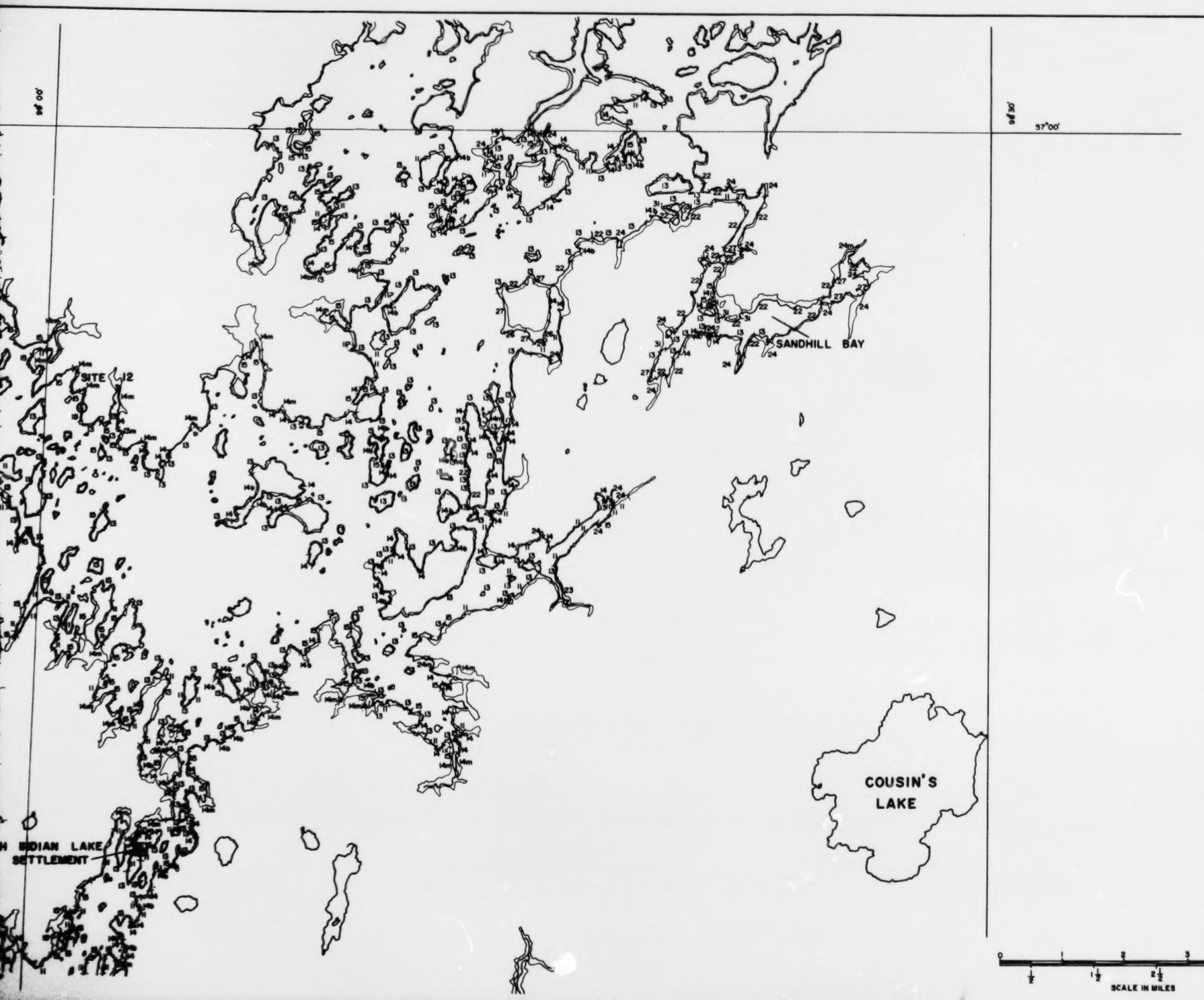
The six miles of Type 24 and two miles of Type 23 shoreline are confined primarily to mouths of rivers feeding into the lake. All other shoreline types are less than one mile each.

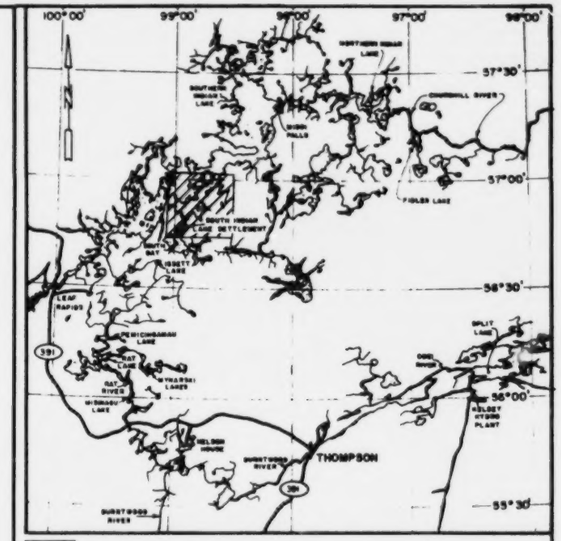


PROFILE OF A BEDROCK CONTROLLED SHORELINE WITH A THICK OVERBURDEN (TYPE 15), SITE 12.

FIGURE 117


N
SITE 12
SOUTH INDIAN LAKE
SETTLEMENT





LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 118

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 6
SHORELINE AND INUNDATED AREA CLASSIFICATION

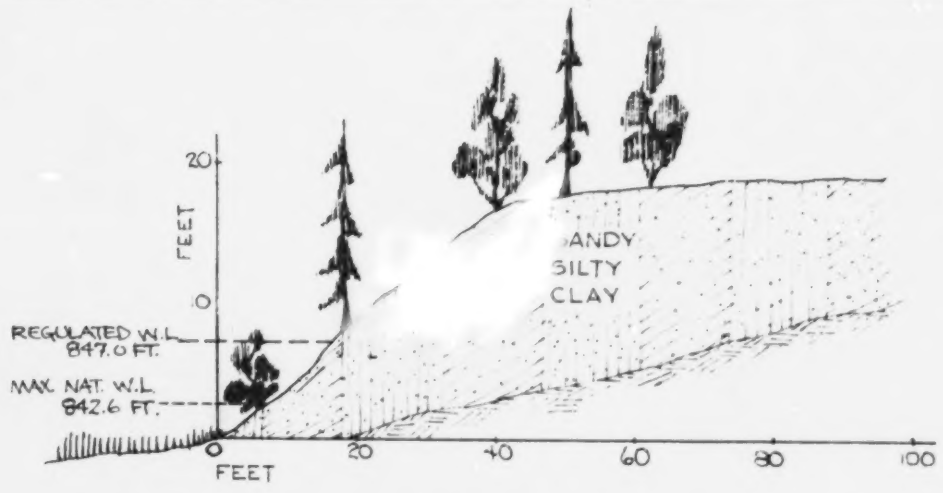
PREPARED	DRAWN	CHECKED	SUBMITTED	RECOMMENDED
D.S.	A.P.E.N.S.	T.M.	DATE	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL /76	29 of 58	61-1-1026

Reach 7 - South Bay: The 93 miles of shoreline in this reach includes South Bay, Poplar Narrows and Swan Bay (Figure 121). The site location of the included profile is an shown in Figure 121. This reach can be distinguished from the other reaches by the reduction in number of islands and the thick lacustrine clay overburden. The clay deposits in the southern portions of the reach are up to 60 feet thick. The extent of the overburden in the southern area is as indicated in Figures 119 and 120.

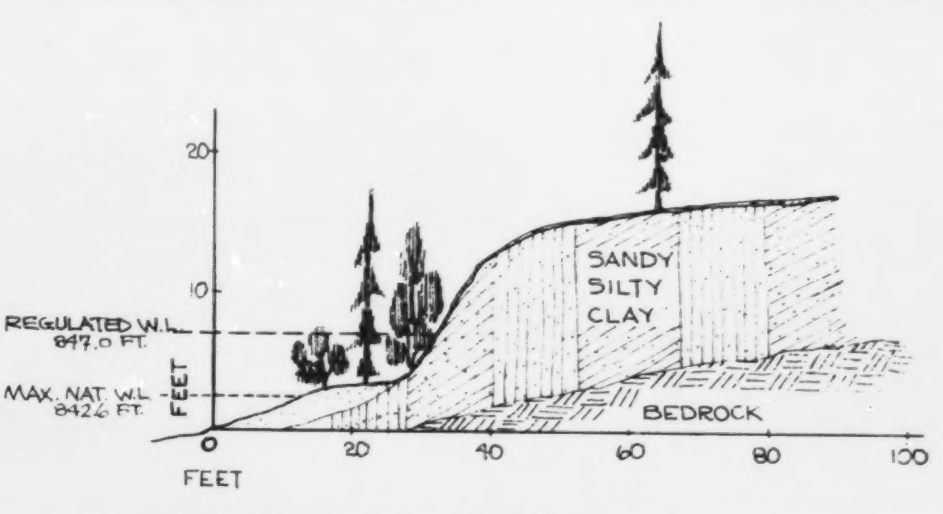
In this reach there is a predominance of Type 14 (34 miles), Type 15 (17 miles), and Type 11 (5 miles).

Within this reach there is a marked absence of granular shorelines and reoccurrence of Type 26 (8 miles) due to the local low relief and materials. The two miles of Type 24 shoreline are located throughout the area.



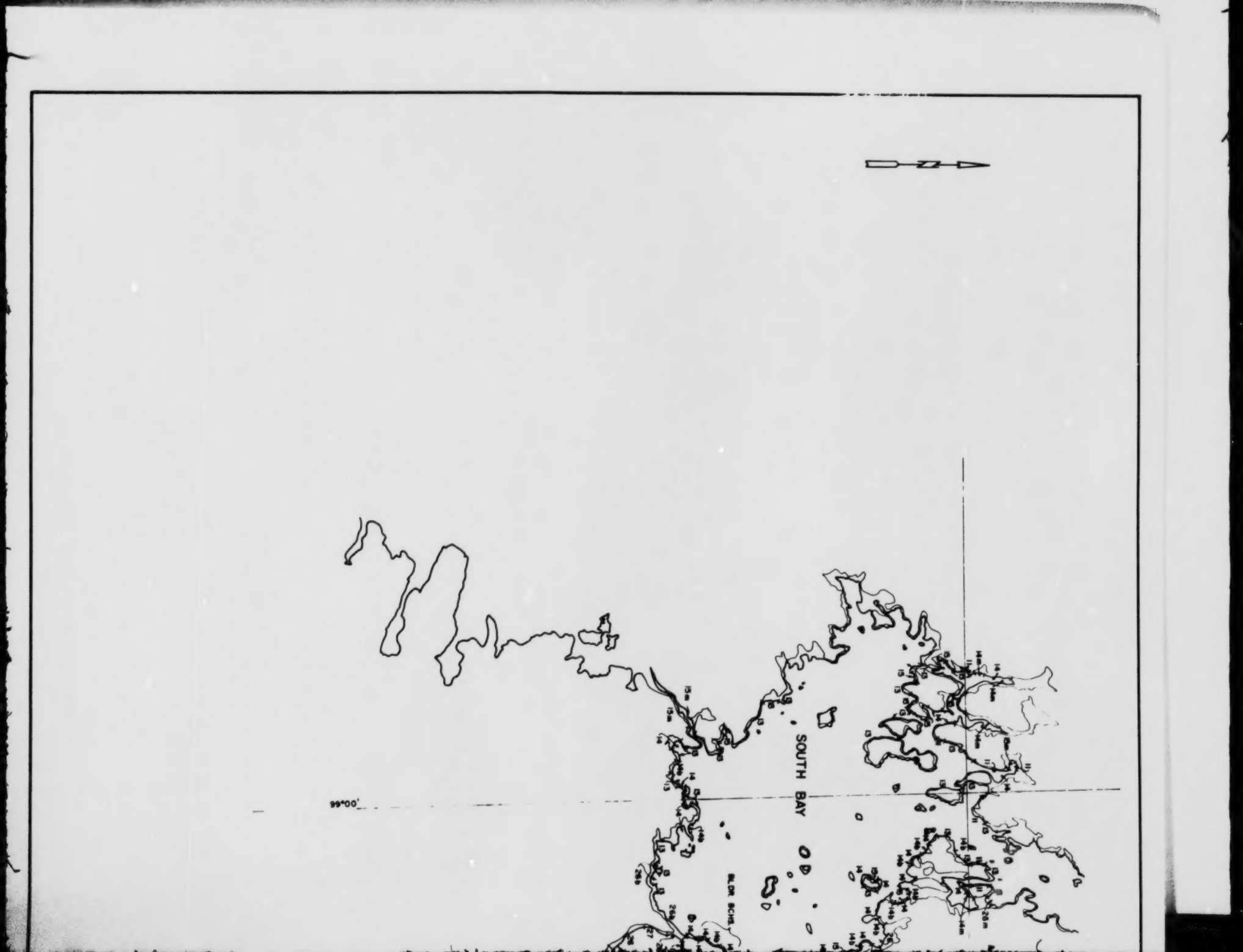
PROFILE OF LOW BEDROCK CONTROLLED SHORELINE WITH A THICK BACKSHORE OVERBURDEN (TYPE 15), SITE 13.

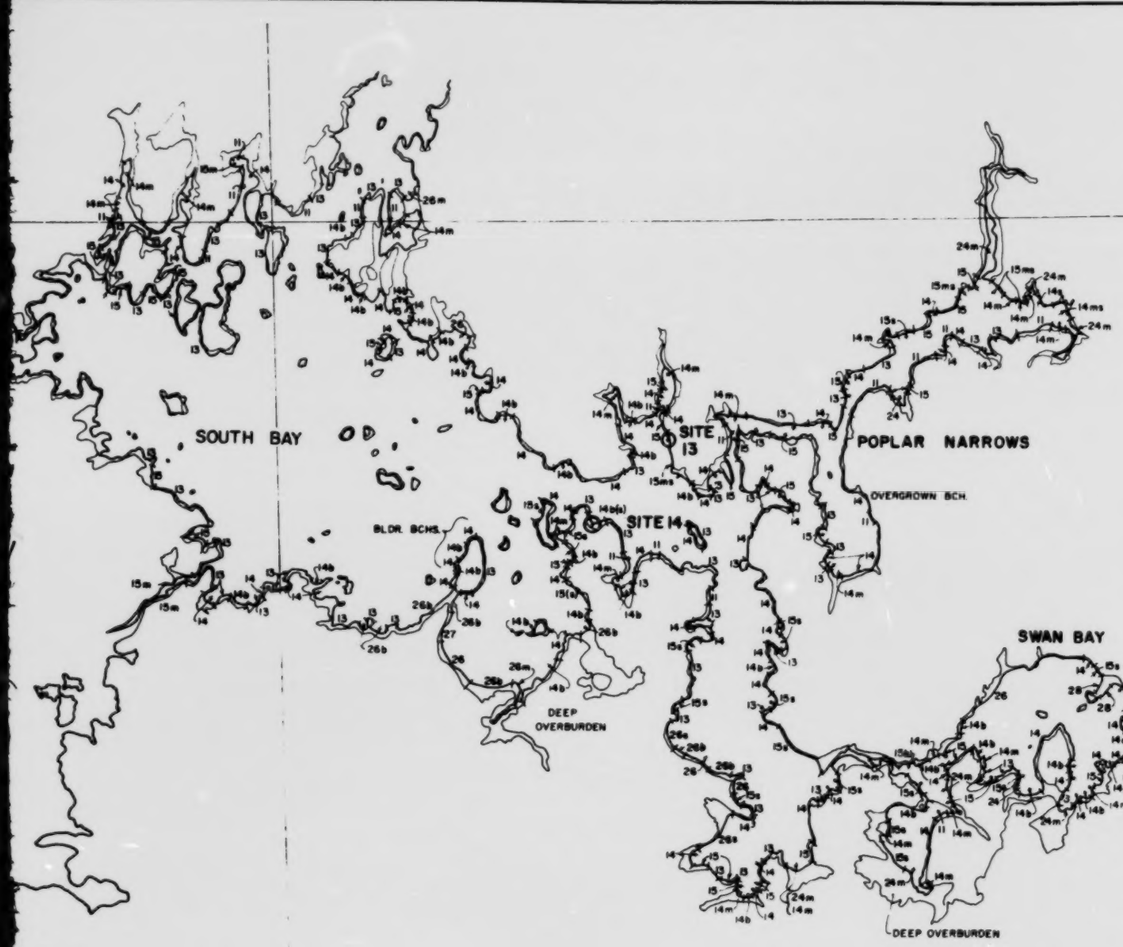
FIGURE 119

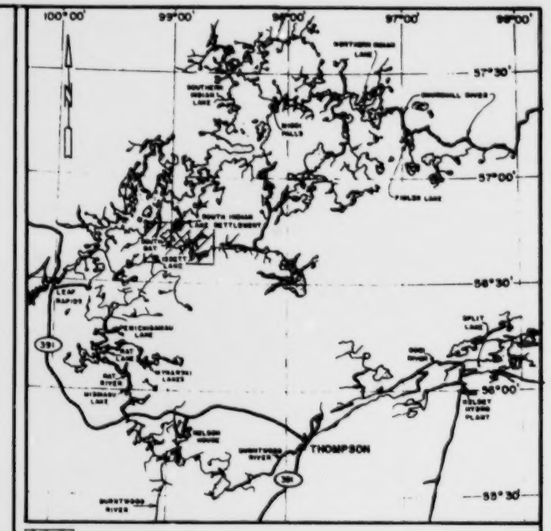


PROFILE OF A BEDROCK CONTROLLED SHORELINE WITH AN OVERBURDEN BEACH (TYPE 14), SITE 14.

FIGURE 120


SOUTH BAY
BLDR SCHS
99°00'





LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

SCALE IN MILES

FIG. 121

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

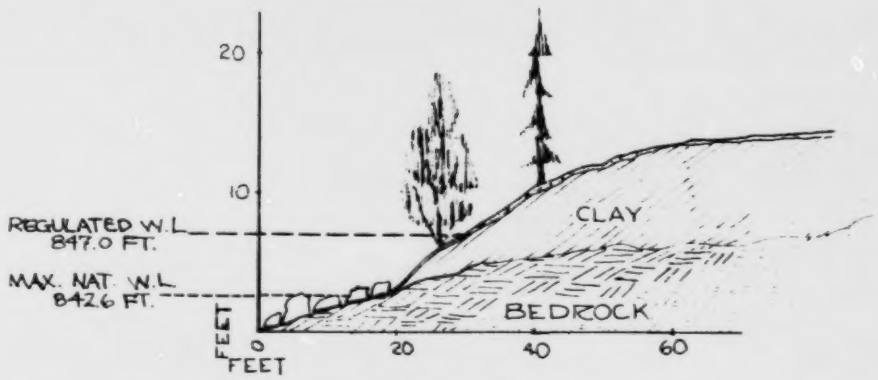
PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 7
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED DATE	APPROVED DATE
D.S.	K.S.	T.M.		

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	30 of 58	61-1-1026

Reach 8 - Opachuanau: The 102 miles of shoreline in this reach includes Opachuanau Lake and the Barrington River (Figure 123). Site locations of the included photographs and profiles are as shown in Figure 123. The area is characterized by the wide variety of shoreline types it exhibits. As in the other reaches, the predominant shore is bedrock, nine miles of Type 11, 75 miles of Type 13B, 7 miles of Type 14 and 3 miles of Type 15. Smaller amounts of Type 24 and 31, 2 miles each, exist throughout the lake while all other types are each less than one mile. Angular boulders are common on low bedrock shorelines (Photograph 110, Figure 122) while many of the overburden beaches are characterized by a marsh zone (Photograph 111).

PHOTOGRAPH 110 - Reach 8, Site 15. Angular boulders on a Low Bedrock Shoreline (Type 13B) on Opachuanau Lake.



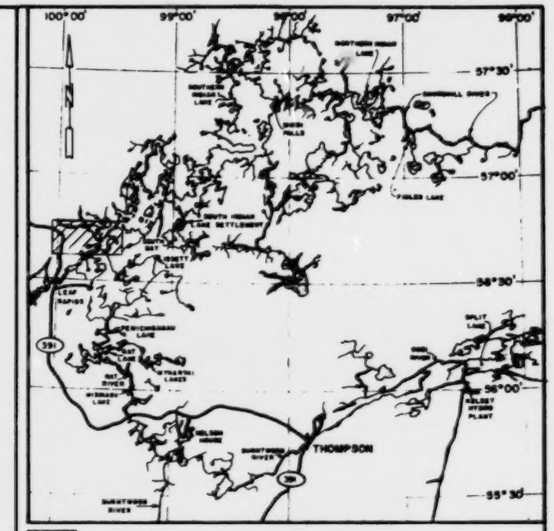
PROFILE OF A LOW BEDROCK SHORELINE (TYPE 13B), SITE 15.

FIGURE 122

PHOTOGRAPH 111 - Reach 8, Site 16. The offshore areas are extremely shallow in the majority of the embayments (Type 14b, m).

Reach 9 - Leaf Rapids: Reach 9 includes the portion of the Churchill River extending from Leaf Rapids to Opachuanau (Figure 124). Of the 65 miles of shoreline, the majority is bedrock controlled. The alternating Types of 11, 13, 14 and 15 make up 9, 34, 7 and 8 miles of rivershore respectively. Types 24 (4 miles) and 28 (2 miles) occur commonly along the tributaries and bays of the Churchill. The remaining shoreline types are less than one mile each.

D-23



= LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

0 ½ 1 1½ 2 2½ 3 3½ 4 4½
SCALE IN MILES

FIG. 123

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

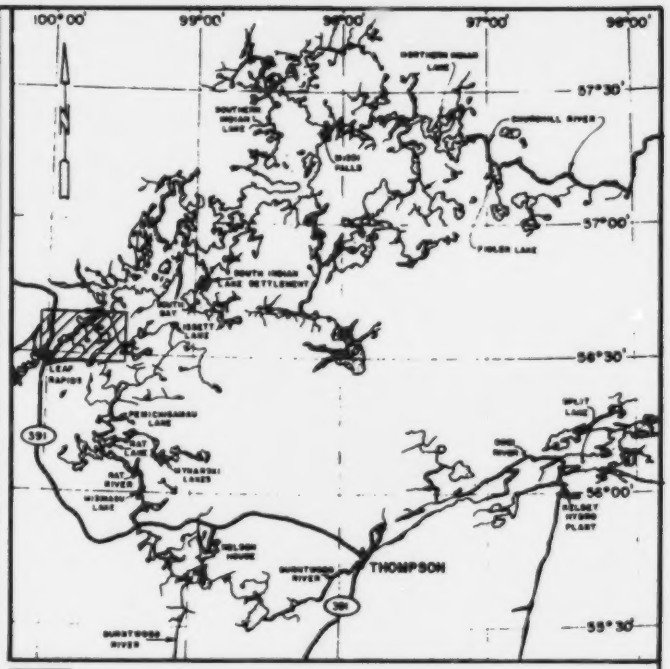
CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 8 (
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED	DATE
D.S.	R.P. & N.S.	T.M.		

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	31 of 58	61-1-1025

N
RUSTY
LAKE
CHURCHILL
RIVER
LEAF
RAPIDS
100° 00'
56° 30'



LOCATION PLAN

0 20 40 60

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
X x X x	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 124

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
SOUTHERN INDIAN LAKE
REACH 9
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED DATE	APPROVED DATE
D.S.	R.P.f M.S.	T. M.		

SCALE	DATE	DRAWING NO.	FILE NO.
AS SHOWN	APRIL/74	32 of 50	61-1-1025

0 1 2 3 4
½ 1½ 2½ 3½ 4½
SCALE IN MILES

Inundated Area: The area to be inundated as shown in Figures 108, 111, 112, 113, 116, 118, 121, 123 and 124 lies between the natural shoreline with a mean water level of 836.5 feet and the 850 foot contour. Under the low level flooding scheme the acreage of Inundated Terrain, as classified by the Physical Impact Study, will be low. Incremented water levels will in most cases remain within the backshore environment characteristic of the flooded shoreline.

The discussion on inundated areas will largely be confined to the northern portions of Southern Indian Lake, Reach 1. In these lowlying regions flooding will extend back beyond the natural shoreline area for one to two miles.

In the Moss Lake Region flooding will be greatest along the low relief shorelines, primarily Types 24 and 31. Localized inundated areas consist of a variety of Treed Muskeg, Treed Muskeg with Permafrost and Sedge Communities. This low-lying, poorly drained region contains very little exposed bedrock typical of most of Southern Indian Lake.

In the Waddie Region, flooding will be greatest a long the Waddie River. The majority of the area to be inundated consists of Treed Muskeg and Sedge Communities (Photograph 112). This region differs from Moss Lake in that the surficial overburden is primarily silt and/or sand and not clay.

The backshore flooding will occur mostly along Type 24 and 31 shorelines as well as Type 22 and 26.

PHOTOGRAPH 112 - Waddie River. Flooding at the mouth of the Waddie River will extend beyond the fen into the forest.

6.4.2 WATER LEVELS AND FLOWS - LEAF RAPIDS TO MISSI FALLS: Figure 125 shows the natural and regulated monthly maximum, median and minumum Southern Indian Lake levels. Maximum levels will be increased by approximately 4.5 feet, minimums by 12 feet. The mean level will be increased by approximately 10 feet. Levels will normally be lowest in mid-to-late winter, rising to highest levels at 847.0 during the summer, and then dropping during early winter. The natural pattern is somewhat similar, with peak levels in mid-summer and lowest levels in late-winter. Falling levels generally occur earlier in the summer than will occur with regulation. The range of levels (from maximum to minimum) will be considerably reduced by regulation from 8.5 feet to 1.3 feet, i.e. water levels will be essentially constant. The water levels stated above are static water levels and do not include wave set-up levels which result in shoreline effects to a higher elevation. The magnitude of the effects will be approximately the same with regulation as in the natural state. Shoreline effects will be experienced to elevation 850 or higher depending on the location.

Short-term (monthly) fluctuations will be greatly reduced by regulation from the natural maximum of nearly four feet (occurring once in four years in June) to a regulated maximum of less than one foot. April through November will generally be months of rising water levels. Falling levels will generally occur during January, February and March. In the natural state, rising levels generally occur during May through August, and falling levels during the rest of the year.

The various water level parameters are outlined in Table 35.

TABLE 35

SOUTHERN INDIAN LAKE LEVELS

	Natural	Regulated	Total
Minimum	834.1 (Feb. to May)	845.7 (Mar., Apr.)	+11.6 feet
Mean	836.5	846.8	+10.3 feet
Maximum	842.6 (July)	847.0 (all months)	+ 4.4 feet
Long-term range	8.5 feet	1.3 feet	- 7.2 feet
Max, monthly fluctuation rise	$\leq$ 4 feet (May, June, July)	$\leq$ 1 foot (all months)	
drop	$\leq$ 2 feet (Aug. to Mar.)	$\leq$ 1 foot (Sept. to May)	

The very sparse data on water levels for that portion of the Churchill River between Leaf Rapids and Southern Indian Lake is summarized in Table 36.

TABLE 36

NATURAL WATER LEVELS IN CHURCHILL RIVER

FROM LEAF RAPIDS TO SOUTHERN INDIAN LAKE

Location	Water Level	Date	Reference
1500' upstream of PR391 bridge	851.4	Fall 1969	Underwood & McLellan Dwg # 217-27-0020
1000' downstream of PR391 bridge	849.80	Fall 1969	Underwood & McLellan Dwg # 217-27-0020
6500' downstream of PR391 bridge	843.26	Fall 1969	Underwood & McLellan DWG # 217-27-0020
Fish Plant,	839.5	April 25, 1974	Surveys Branch
5 miles downstream of PR391 bridge	841.2	Feb. 1972	Flower and Beattie Land Surveyors
Southern Indian	837.5	Fall 1969	Water Survey of Canada
Lake at South	837.6	Feb 1, 1972	Water Survey of Canada
Indian Lake	838.0	April 1, 1974	Water Survey of Canada

The data indicates that the Churchill River drops approximately ten feet over a distance of about five miles from the PR391 bridge to the Fish Packing Plant and that the level of Southern Indian Lake will affect the level of the Churchill River up to some point within this five mile reach both under natural and under regulated conditions.

For purposes of this report, the level of the Churchill River at the Fish Packing Plant is taken to be 4.5 feet and three feet higher than the level of Southern Indian Lake for natural and regulated conditions respectively. At intermediate points along this reach of the River, the river levels for this reach would then be approximately as given in Table 37.

TABLE 37

MEAN WATER LEVELS IN CHURCHILL RIVER FROM FISH PACKING

PLANT AT LEAF RAPIDS TO SOUTHERN INDIAN LAKE

Location	Natural	Regulated	Change
From Fish Packing Plant to First Rapids downstream	841	850	+ 9
From First Rapids downstream of Fish Packing Plant to inlet to Lake Opachuanau	839.5	849	+ 9.5
Lake Opachuanau	838	848	+10
Southern Indian Lake	836.5	847	+10.5

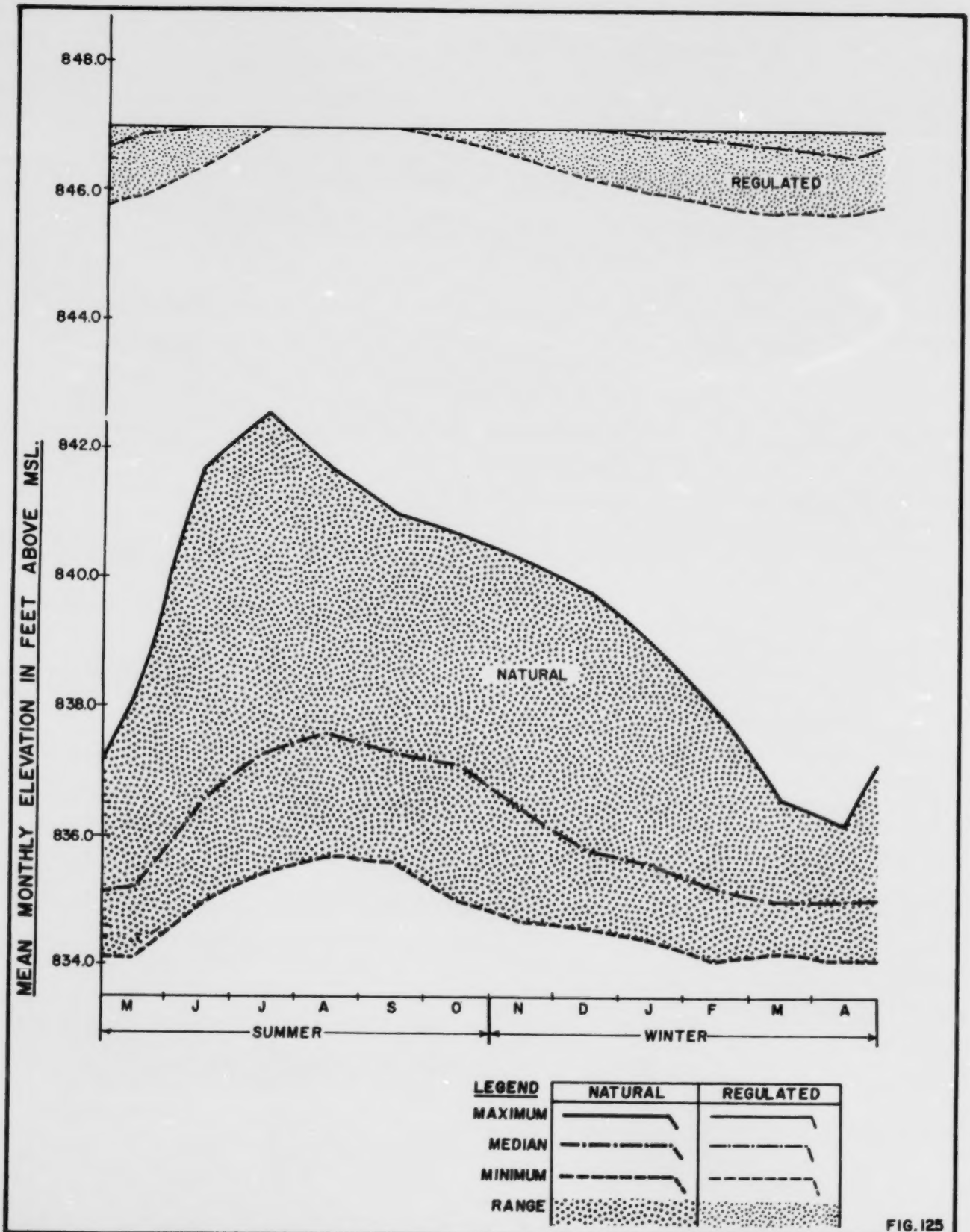


FIG. 125

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS AT SOUTHERN INDIAN LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.	DATE	DATE
	CHECKED F.P.	J. Penner	J. Bruntey

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN/74	33 OF 58	61-1-1025

6.4.3 IMPACTED STATE CONDITIONS - LEAF RAPIDS TO MISSI FALLS: Reaches included within the Leaf Rapids to Missi Falls area will not only be affected by the raising of the water levels but also by the change in the water level fluctuation regime.

The effect of raising the natural mean water level of 836.5 to 846.8 an increment of 10.3 feet, is as discussed under Low Level Flooding of "Impact Process Statements for Shorelines" and Impact Process Statements for Inundated Terrain, Sections 5.4.1 and 5.4.3.

The water level regime under regulated conditions will vary from the natural state in that the long term range of fluctuations will be reduced from 8.5 feet to 1.3 feet. This almost constant water level under regulated conditions is pertinent as it will have a marked effect on the actual width of the water washed zone. The reduction in beach width will be especially evident on the low bedrock shorelines (Type 13, 14b, 15b), coarse material beaches (Type 22 and 27) and the clay bank shorelines (Type 23). The reduction in water level fluctuations will not only effect the width of Type 24, 28 and 31 shorelines but also strongly influence the plant successional processes. Rather than the marsh species (hydrophytes) predominating over a wide area, they will be restricted to a narrow zone along the water edge. This becomes noticeably important when discussing Fen Shorelines (Type 31) as the young sedge sere is retained due to natural maximum monthly fluctuation. Under regulated conditions the maximum fluctuation of two feet will reduce the width of the sedge-sere zone.

A discussion on each of the nine reaches follows.

Reach 1 - Moss Lake, Hammond Point, Waddie River: In terms of inundated area and reflected shorelines, the impact will be the severest in reach 1 of the Southern Indian Lake area. The low relief and permafrosted mineral soil characteristic of this area are in general not conductive to the formation of a natural looking shoreline. Portions of the new shoreline will be cluttered with driftwood while embayment will be conjested with standing and fallen trees.

The Moss Lake region will contain several square miles of inundated trees. The high occurrence of Type 24 shoreline (50%) is indicative of the low nature of the terrain and the extent of flooding to be expected. Upon inundation, the Little Sand and Muskwesi River system will become portions of a newly created lake. The marsh communities found along the western shore of Moss Lake and the extensive river system will in all likelihood not develop to the extent they were in the natural state within a 50 year period. The large acreage of Fen shorelines and Sedge Communities are expected to rise with the water level increment. These matts will remain within the general area due to the low level of flooding and extent of standing flooded trees.

The eastern granular and bedrock shore of Moss Lake will achieve a natural state within the 50 Year Time Period. The ultimate state of all other shorelines is dependent upon the local depositional and/or erosional processes. Most of this region will not obtain a natural appearance within the 50 Year Time Frame.

The noticeable effects of flooding in the Central Region will be the formation of islands from the many peninsulas.

The alternating series of bedrock control and coarse material shorelines will achieve a stabilized state within the 50 Year Time Frame. Due to the low relief in this region, the regulated water line will be set back 120 feet plus along most of the Low Bedrock Shorelines. The overburden can be expected to be eroded back at least 20 feet before the shoreline stabilizes. Shoreline erosion will likely be somewhat less along Types 14 and 15 shorelines. Beaches and marshes typical of Type 14 will not redevelop to the extent they were under natural conditions.

Horizontal flooding will be greatest in the areas north of Hammond Point where the shorelines are predominantely Type 24 and 28. In this area marsh vegetation will be flooded out and not be redeveloped. The long sweeping beaches in the southeastern portion of the region will attain a stable state early in the adjustment phase. At these sites the water line will be set back 100 feet.

In general the Waddie Lake area will quickly recover due to the extent of the granular materials. Backshore flooding will be greatest along Type 24 and 26 shorelines. The extensive fen characteristic of the river mouth area will become free floating under a 10 foot water level rise. Fen materials will not break down as was observed at Sipiwesk Lake under similar flooding conditions. These free floating sedge matts will likely be instrumental in forming portions of the new shoreline in both the Waddie and Moss Lake Regions.

Reach 2 - Missi Falls: This reach will not be affected as seriously as Reach 1 due to the higher occurrence of bedrock shorelines and steeper relief. Of all impacted shorelines, Type 11 shorelines will be affected the least. In this case, the water line will be set back about 20 feet. Shorelines will be set back 40 to 60 feet above the maximum water level along Type 14 embayments. Natural state shorelines (Type 22) will be achieved the soonest within the northern esker-kame complex.

Overall, the raised water levels will have the effect of inundating most of the smaller islands while reducing the acreage of all others. In general the islands within all nine reaches of Southern Indian Lake will recover at a faster rate than the mainland due to their bedrock control and exposure to wave, winds and moving ice.

Reach 3 - Long Point: Due to the increasing depth of overburden and greater relief in this reach, a fair amount of erosion will occur along the low bedrock shorelines (Type 13B and 15). Under these circumstances, a stable state shoreline will be achieved within a short time span. The extensive granular beaches characteristic of Type 14 shorelines will likely be reformed to some extent due to the source of materials in the nearby area. Types 24 and 28 will be characterized by the dead standing trees and likely take the longest to achieve stability.

Upon inundation Long Point will become an Island, thereby decreasing the traveling distance from the settlement to Loon Narrows. Type 28 embayments peculiar to this peninsula will take the longest to recover.

The high occurrence of Type 11 and 22 shorelines in the southern portion of the reach will undoubtedly lessen the impact.

Reach 4 - Mulcahy Lake: Of all the nine reaches in Southern Indian Lake the shoreline impact will be the lowest in Reach 4 due to the large proportion of Type 11 shoreline (60%) and low occurrence of low relief shorelines (Types 24, 28 and 31). The remainder of the shorelines are bedrock control. Flooding will be greatest within the many tributaries and bays of this reach, where Type 24 is the predominant shoreline.

Reach 5 - Lemay Islands: The impact along these bedrock shorelines will be similar to that of Reach 2. The Type 13B clay banks are expected to erode back about 20 to 40 feet before the shoreline stabilizes. The large proportion of Type 14 marshes and overburden beaches will not be entirely re-established within the Fifty-Year Time Frame. Along these low overburden beaches the shoreline will be set back around 100 feet.

The vast majority of the islands will not be inundated but just reduced in size. Bedrock control embayments will remain congested with dead standing and fallen trees for a fifty-year period.

Reach 6 - South Indian Lake Community: Bedrock control shorelines will be affected no differently than those already mentioned in the preceeding reaches.

The granular shorelines in the Sandhill Bay area are expected to be the first to achieve a stable state.

The anticipated shoreline impact in the immediate area of the community has been covered in another study (Reference 20).

As a result of the diversion, water velocities will substantially increase in the channel intersecting the settlement. Consequently, a normal ice cover is not expected to form under the new flows (Reference 21).

Reach 7 - South Bay: In terms of overburden erosion the shoreline impact is severe in this reach as South Bay is characterized by a deep clay overburden. For this reason a considerable amount of erosion and shoreline recession can be expected along the bedrock control shorelines. The extent of the recession will likely be in the magnitude of 60 to 80 feet before bedrock is reached. Impacted steep overburden banks will take on the appearance of impacted clay banks of Sipiwesk Lake, on the Nelson River system. In general the predominance of Type 14 and 15 shorelines becomes significant as a greater time period is required for these shorelines to reach stability. Flooding will be greatest horizontally along Type 24 and 26 shorelines. Such areas will remain congested with fallen and dead standing trees.

Manitoba Hydro has undertaken a slash-only operation to the 850 foot contour on the Southern shore and immediate islands of South Bay. The justification of such an operation is questionable as the overburden banks will erode beyond the cleared tree line. Once the Churchill River is diverted through South Bay, the felled trees will float into Notigi Reservoir. Floating debris generated from South Bay may not reach the Notigi dam site but will likely collect along the shoreline of the upper reservoir.

Reach 8 - Opachunanau: This reach will not be affected as seriously as South Bay. The impact on the granular and bedrock controlled shorelines will be

similar to that discussed in other reaches. In general, the granular and bedrock shorelines are expected to stabilize the soonest. River shores are expected to achieve a natural appearance before the lake shores due to the clearing effect of the water velocities and ice movements on trees and overburden.

Reach 9 - Leaf Rapids: The impact on Reach 9 shorelines will be similar to that of Opachuanau. The narrower portions of the channel will likely be cleared of cover and overburden before the larger embayments. Embayments consisting of Types 24 and 28 will affected most severly.

6.4.4 SUMMARY STATEMENT - LEAF RAPIDS TO MISSI FALLS: The stretch of waterway from Leaf Rapids to Missi Falls includes a portion of the Churchill River, Opachuanau Lake and Southern Indian Lake. Along these bodies of water are 1,812 miles of shoreline. Southern Indian Lake, by far the largest body of water, is fed at its south-west arm by the Churchill River via Opachuanau Lake and smaller waterways - the Barrington, Muskwesi and Waddie Rivers. Outflow is via Missi Falls and Missi Rapids at the north-east portion of the lake.

Southern Indian Lake is characterized by a variety of shoreline types. The majority are bedrock shorelines; marsh and granular beach formations are evident within embayments. The northern section of Southern Indian Lake is characterized by low relief and esker formations. Consequently, the highest occurrence of granular shorelines (sand and gravel beaches) and low lying shorelines are to be found in this region. Low areas are characterized by winding rivers, extensive marshes and treed muskeg. In contrast the southern section of Southern Indian Lake (South Bay) is characterized by high relief and thick lacustrine clay overburden.

After regulation of the level of the Lake and the associated raising of water levels, the Churchill River will be redirected to flow out of South Bay into the Rat-Burntwood system. The area from Leaf Rapids to Missi Falls will not only be affected by the increment in water levels, but also by the change in water level fluctuations. From the natural mean to the regulated mean, the water surface will be raised 10.3 feet. The change from natural maximum to regulated maximum is 4.5 feet. Under regulated conditions, the range of water level fluctuations which is 8.5 feet under natural conditions will be reduced to 1.3 feet. Water levels will vary less under regulation.

Although the actual water level increment is not great, the reduction in fluctuations will cause a reduction of the width of the water- washed zone. This will affect the formation of granular and alluvial beaches and marshes.

The impact along the majority of shorelines will be erosion of the overburden until bedrock is reached. Such shorelines will be cluttered with debris (fallen and standing trees) for at least fifty years. Within this period, headlands will tend to clear, but embayments are sites of accumulation. A reduction in the range of water levels will reduce the width of the rock washed zone.

The granular type beaches near esker formations are expected to stabilize within a ten to twenty year period.

Marsh zones will be substantially reduced and will not be re-established to the extent they were in the natural state.

In general, the effect of regulation will

be to reduce the diversity of shoreline types, increase the shoreline distance, inundate small reefs and islands and create large islands from peninsulas being separated from the mainland.

6.5 LOWER CHURCHILL RIVER - MISSI FALLS TO HUDSON BAY

6.5.1 NATURAL STATE CONDITION - MISSI FALLS TO HUDSON BAY:

The term "Lower" refers to that segment of the river between Southern Indian Lake and the Hudson Bay, a distance of some 280 miles.

This report has subdivided it further into characteristic reaches, or, those stretches which embody similar characteristics in terms of vegetation, shoreline material, slope, unique features, etc.

Initially, it is of value to simply comment on the river as an entity. The river, in this part of the province, flows through an area of the Canadian Shield, an area of Paleozoic Limestone, and then Precambrian Sandstones. The shield is covered, almost throughout, with a thick mantle of glacial till, the till containing sands, silts and clays as well as some boulders. As Hudson Bay is approached, one finds the river embedded in thick marine deposits.

Rapids are frequent anywhere along the Lower Churchill. The water is clear, and even though turbidity increases downstream, it is still only at minimum levels at the head of the esturary.

The river has formed a valley that embodies several characteristics differing from the surrounding uplands. The uplands of the precambrian are studded with small lakes, muskeg is frequent and the balance is an open black spruce forest. In the case of the uplands above the Paleozoic Limestones the lakes become even more frequent. A heavy peat layer supports only stunted black spruce and in the vicinity of the Bay the uplands are tundra-like. Permafrost is prevalent over the entire area. The river is a store of heat for the valley and in a micro sense the climate is altered significantly. The steep banks are much more heavily vegetated than the uplands, the growth being both taller and denser and the species being more varied (Photograph 113). This effect is apparent in a strip up to one mile wide on each side of the river extending 100 miles along the river. The banks are generally unstable and often they are actively eroding keeping them free of vegetation. A slow decrease in height of the banks is noted from Bad Cache rapids to the estuary. Throughout the estuary, banks are low, poorly drained with occasional slumping. The width is a characteristic that changes significantly according to the bed and bank material. In the Precambrian the width is variable but infrequently over half a mile and generally about a quarter mile. The bed is likewise irregular, the depth in the channel varying from a foot or two up to 30 or 40 feet. The river depth and width becomes much more uniform in the Paleozoic deposits. The bottom is nearly flat and the banks nearly straight (Photograph 114).

The lower Churchill has been divided into several continuous reaches. The mileages of the shore types are shown in Table 38.

TABLE 38

LOWER CHURCHILL RIVER

Mileage of shoreline types

Reaches	Types																
	11	12	13	13M	14	14B	14M	14BM	15	15M	21	22	23	23M	24	24B	24M
Reach 1 Partridge Breast	17.5		118.1		14.2	0.9	0.2		7.2		32.5	9.3	9.4		18.3		
Reach 2 Northern Indian	10.4		88.0	7.0	29.6	1.9	3.6	0.4	34.6	1.8	3.6	10.7	0.9		14.2		0.4
Reach 3 Fidler Lake			6.1		1.2	1.1	0.3	0.2	10.6	0.9		11.3			9.0	0.8	
Reach 4 Fidler Falls			26.0		34.0							0.4	12.0		4.0		
Reach 5 Billard Lake			2.0		4.0							13.6	5.6		12.4		
Reach 6 Billard Rapids			12.0		8.4										0.4		
Reach 7 Upper Canyon			4.8								106.0						
Reach 8 Lower Canyon		22.0									8.0						
Reach 9 Long Island											82.0						
Reach 10 Estuary			5.6												28.0		
TOTAL	37.9	22.0	262.6	7.0	91.4	3.9	4.0	0.6	52.4	2.7	232.1	45.3	27.9	2.4	86.3	0.8	0.4

PHOTOGRAPH 113 - The Upper Canyon about ten miles above the Little Churchill River. The bank rises over 200 feet above the water.

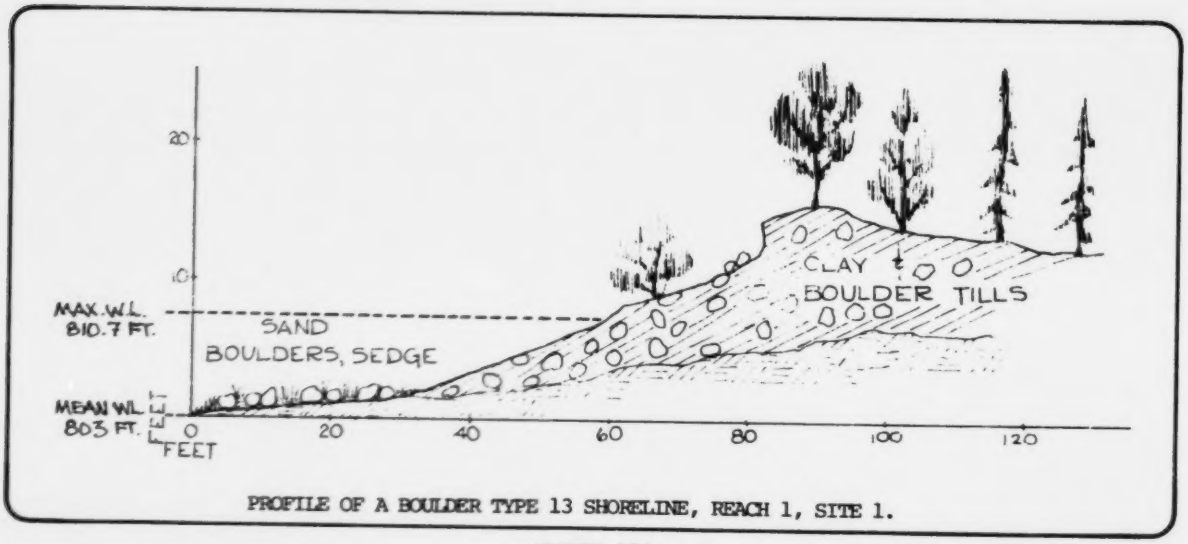
PHOTOGRAPH 114 - Small tributaries are deeply incised into the limestone. This one, Surprise Creek, enters the Churchill in the Lower Canyon.

Reach 1 - Partridge Breast Lake: Reach 1 encompasses the shoreline extending from Missi Falls downstream to the inlet of Northern Indian Lake (Figure 129). Site locations of the included photographs and profiles are as shown in Figure 129. The lake portion of this reach consists of long stretches of Type 13 shoreline interspersed with Type 24 and 14 shoreline. Type 13 shoreline differs from the typical profile drawing by exhibiting a boulder till mantle (Photograph 115, Figure 126). The water washed rock zone is wide (100 to 350 feet) and sparsely colonized by sedges and grasses. The extent of the grass cover is a function of the substrata, typically tills are colonized while bedrock is bare. Normally the offshore zone is devoid of hydrophytes. Shrubs typically form a border along the upper extent of the high water level. This zone is approximately six feet above the mean water level marking the upper limit of the high water level. Type 24 shorelines are extensive in this reach (Photograph 116, Figure 127) while type 14 shorelines are usually covered by coarse grained materials (Photograph 117) or else a till overburden (Figure 128). Shoreline Type 13, 14 and 24 consist of 118, 15 and 18 miles respectively.

Type 15 (7 miles) is only significant in the lower portion of the reach. This area is also characterized by the presence of Type 22 (9 miles) and Type 27 shoreline (3 miles). Tributaries feeding into the channel and lakes consist of Type 23 shoreline (9 miles).

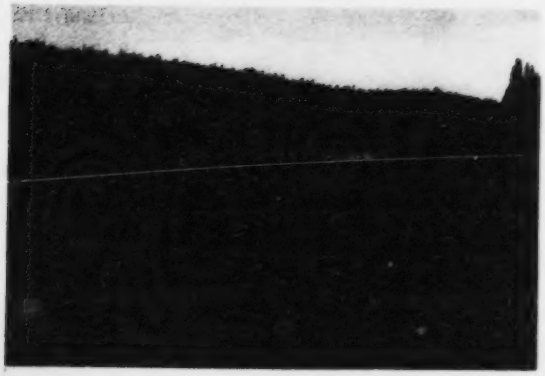
Type 11 and 21 representing 17 and 33 miles of shoreline respectively are confined primarily to the channel sections of this reach.

PHOTOGRAPH 115 - Reach 1, Site 1. A boulder-Type 13 shoreline on Partridge Breast Lake. Note the sparse plant cover on the till materials.

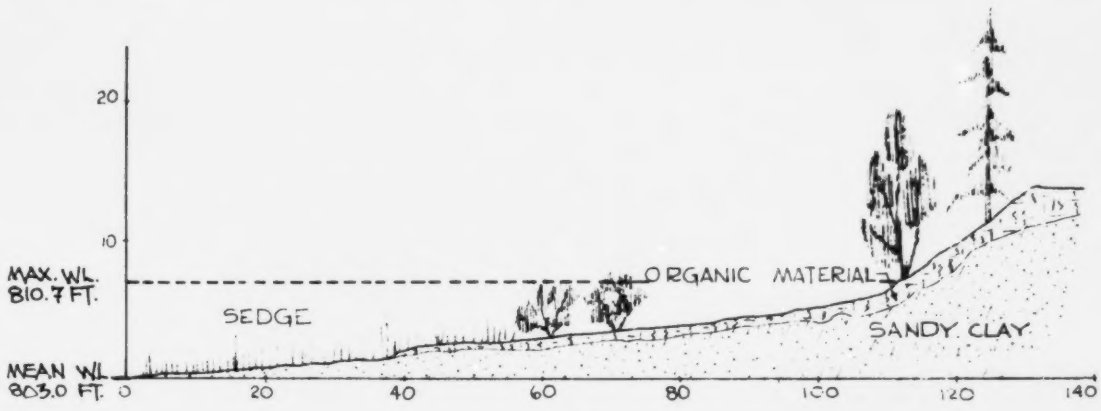


PROFILE OF A BOULDER TYPE 13 SHORELINE, REACH 1, SITE 1.

FIGURE 126

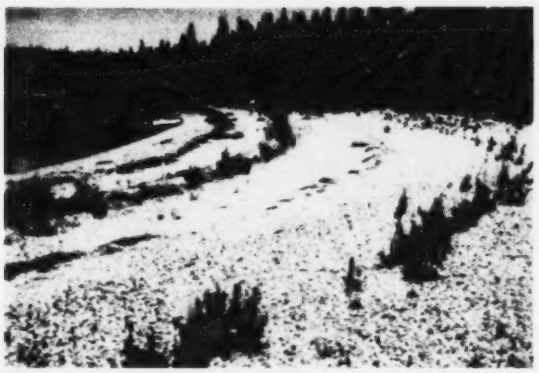


PHOTOGRAPH 116 - Reach 1, Site 4. A Low Alluvial Shoreline (Type 24) on Partridge Breast Lake. The sedge and grass foreshore backed by a fringe of alder and willow is typical of Type 24 shorelines.

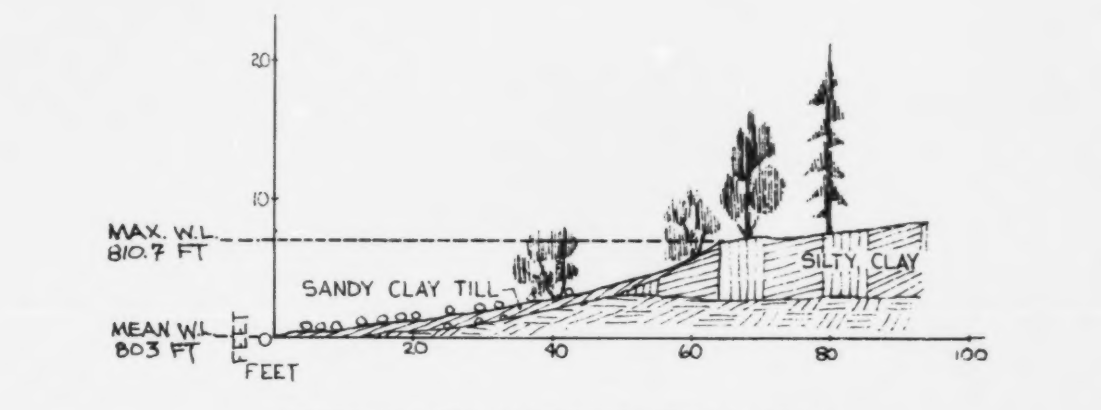


PROFILE OF A TYPE 14 SHORELINE, REACH 1, SITE 4.

FIGURE 127

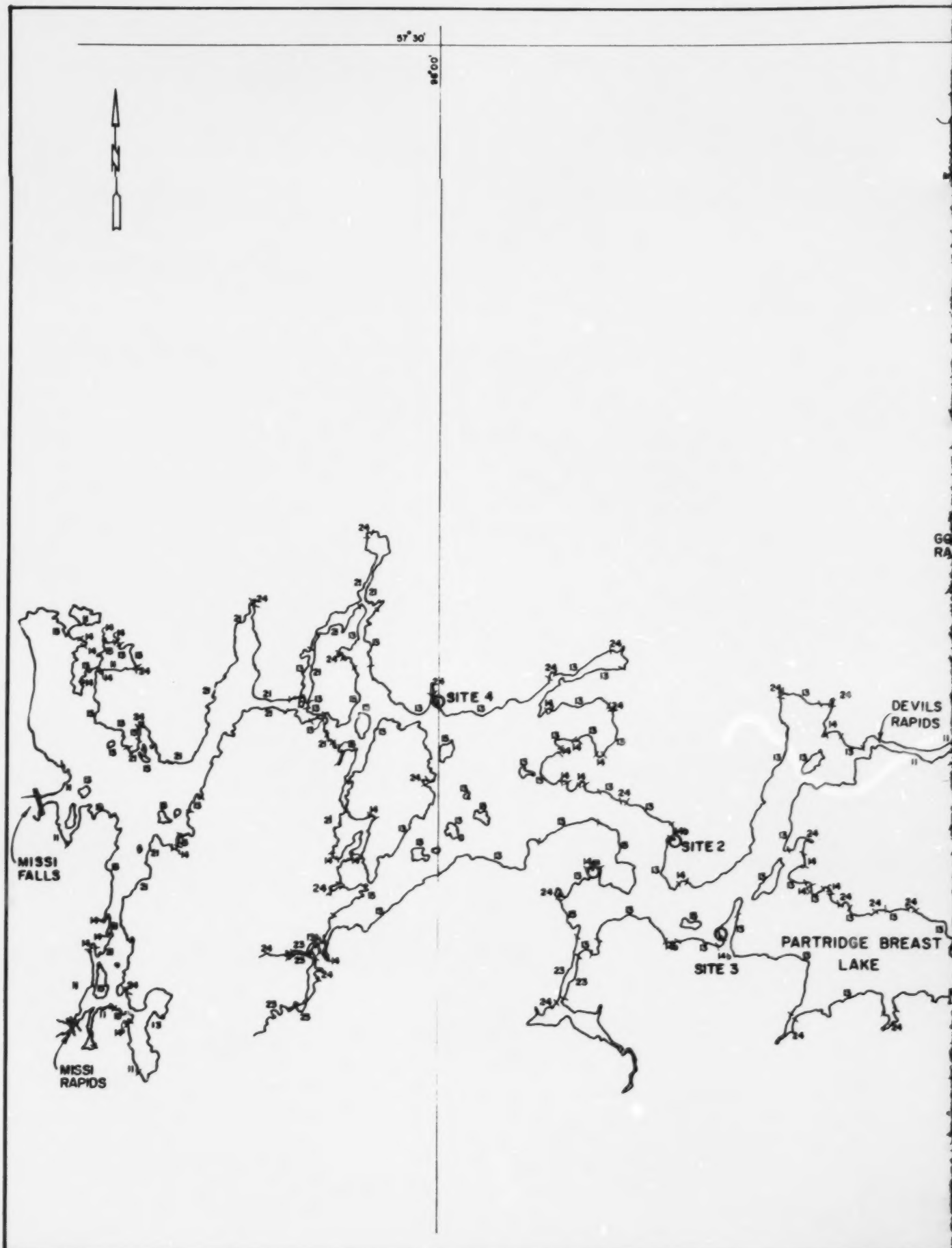


PHOTOGRAPH 117 - Reach 1, Site 2. A Type 146 shoreline on Partridge Breast Lake. The width of the coarse grained beaches is indicative of a large change in water levels along this system.



PROFILE OF A TYPE 14 SHORELINE, REACH 1, SITE 3.

FIGURE 128


57° 30'
98° 00'
N
SITE 4
SITE 2
SITE 3
DEVILS RAPIDS
PARTRIDGE BREAST LAKE
MISSI FALLS
MISSI RAPIDS

REACH NO. 1

GOD'S RAPIDS

CHURCHILL RIVER

DEVILS RAPIDS

SITE 2

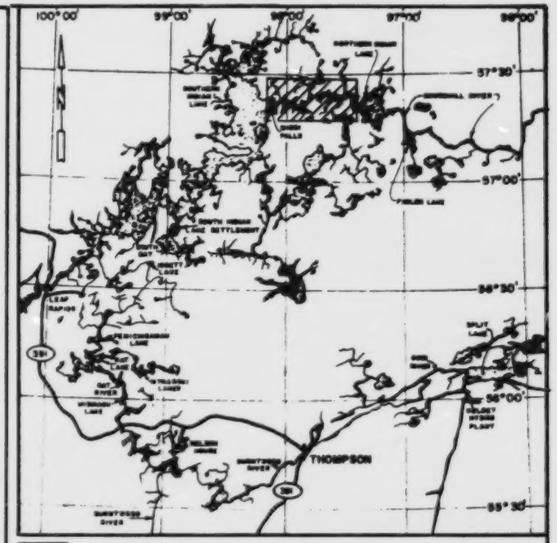
SITE 3

PARTRIDGE BREAST LAKE

SITE 1

GAUER RIVER

SCALE IN MILES



= LOCATION OF MAP

LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
⊥ ⊥	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 129

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

LOWER CHURCHILL RIVER
REACH 1
SHORELINE AND INUNDATED AREA CLASSIFICATION

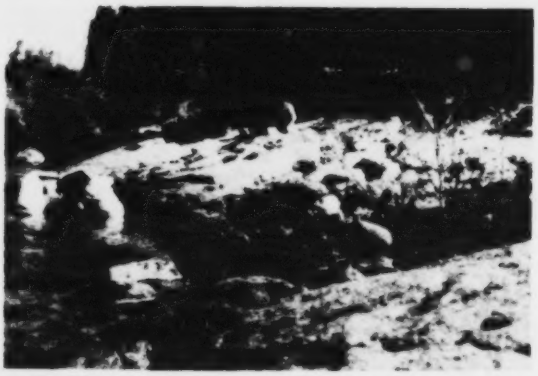
DRAWN	CHECKED	SUBMITTED	RECOMMENDED
D.S.	R.P.E.N.S.	T. M.	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	34 of 58	61-1-1025

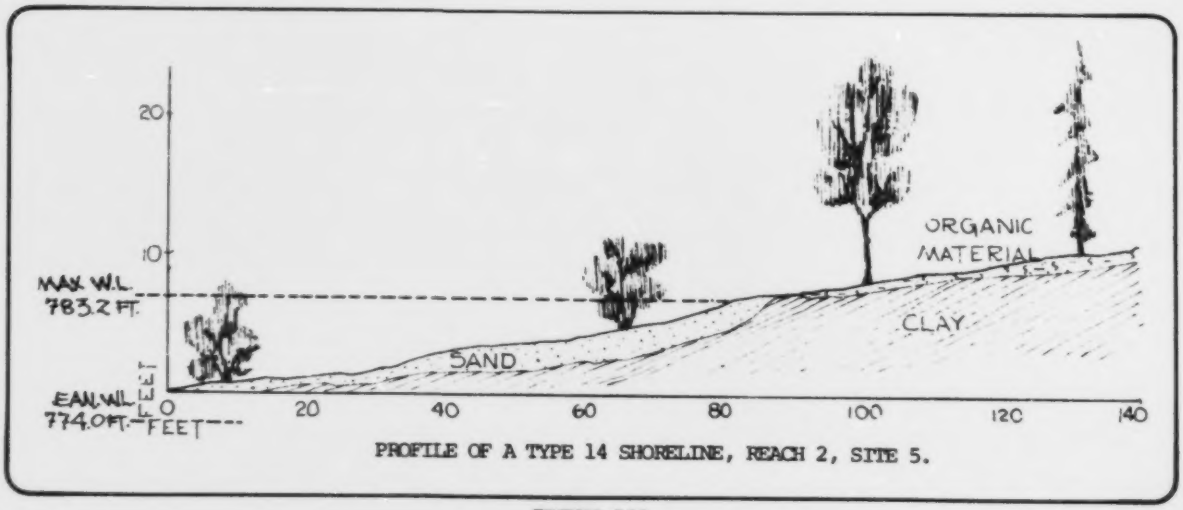
Reach 2 - Northern Indian Lake: This reach includes Northern Indian Lake and the channel to the Kirkness Rapids area (Figure 132). Site locations of included profiles and photographs are as shown in Figure 132. The characteristic aspect of Northern Indian Lake is the alternating series of Types 13, 14 and 15 shoreline consisting of 95, 36 and 36 miles respectively. A higher occurrence of Type 15 is evident in this reach (Photograph 118). Shoreline materials are similar to those of a boulder Type 13 shoreline. Granular beaches can be found along the entire system but are infrequent (Figure 130). Isolated stretches of Type 11 (10 miles) are common throughout the lake while Type 22 (11 miles) is only common to the southern portion. The Type 11 shoreline typical of this system contain a wider water-washed zone than those of Southern Indian Lake (Photograph 119 and Figure 131).

The channel portion of the reach has a higher proportion of Type 23, 31, 21 and 24 shoreline than the lakeshore. These minor lengths of shorelines are 1, 4, 4 and 15 miles long respectively. The lower channel shoreline differs from the lake shoreline due to the occurrence of Type 27 which makes up five miles of shoreline.

PHOTOGRAPH 118 - Reach 2, Site 6. A boulder type 15 shoreline on Northern Indian Lake. Note the graminoids in the narrow boulder zone.

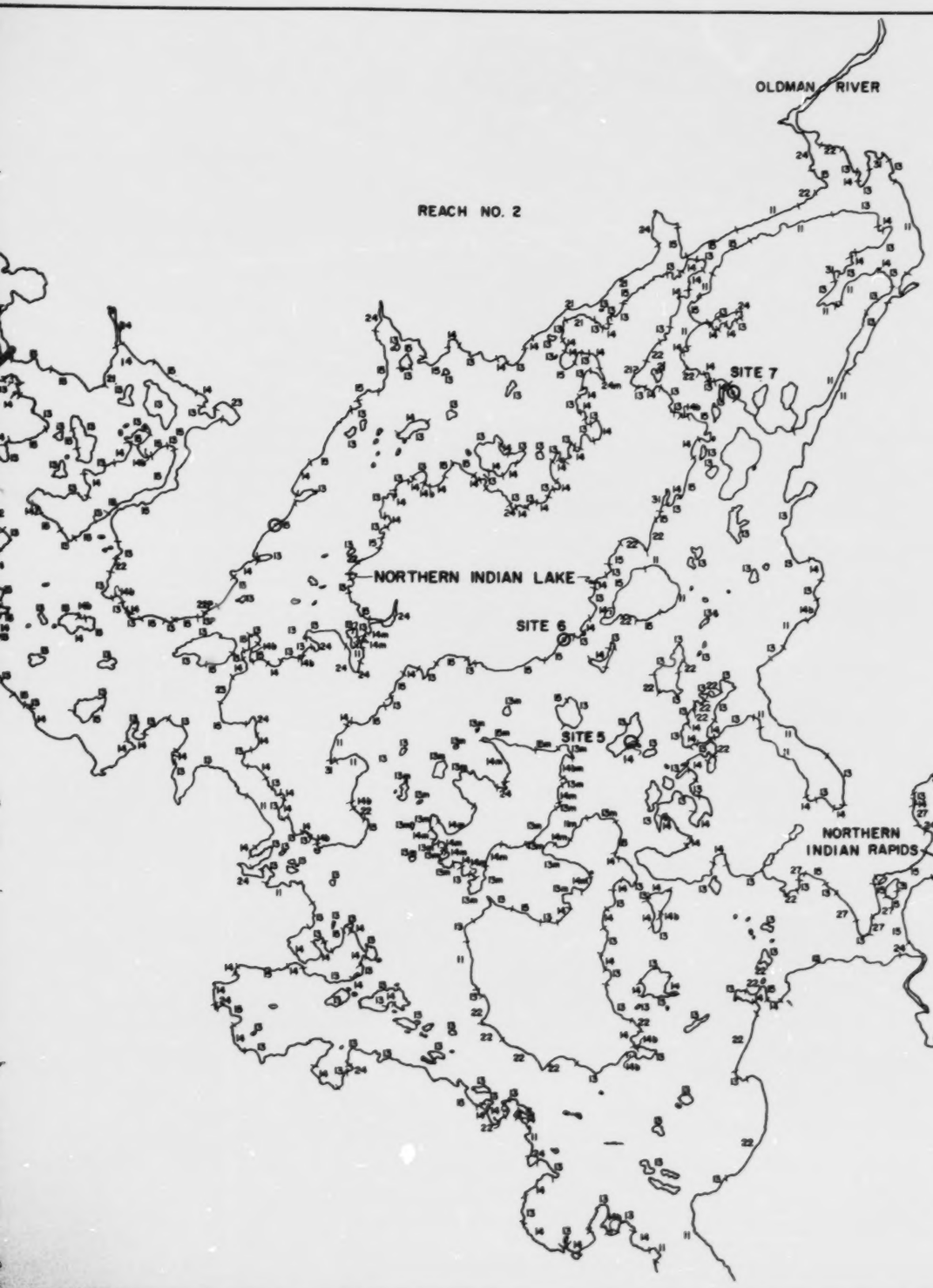


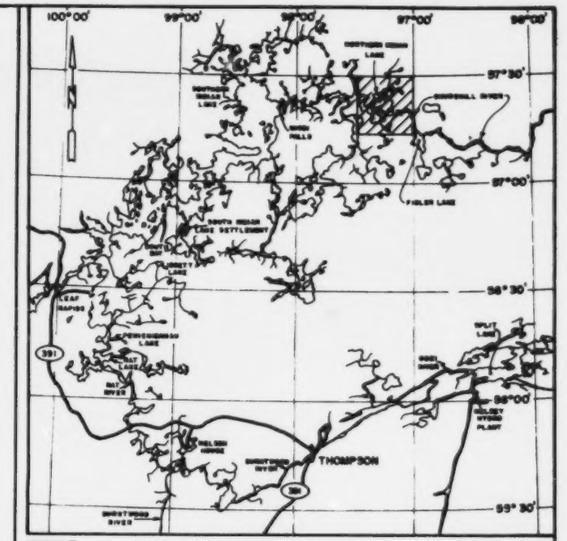
PHOTOGRAPH 119 - Reach 2, Site 7. A steep bedrock shoreline (Type 11) on Northern Indian Lake.



PROFILE OF A TYPE 14 SHORELINE, REACH 2, SITE 5.

FIGURE 130





LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 132

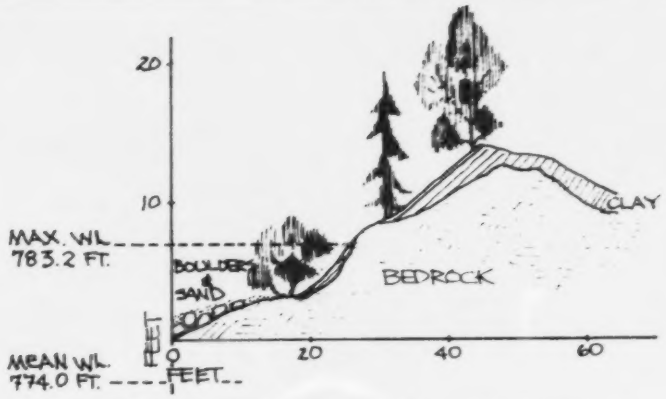
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
LOWER CHURCHILL RIVER
REACH 2
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED
D.S.	R.P. & M.S.	T. M.	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	35 of 58	61-1-1035



PROFILE OF A TYPE 11 SHORELINE, REACH 2, SITE 7.

FIGURE 131

Reach 3 - Fidler Lake: Reach 3 includes the channel downstream from Kirkness Rapids and Fidler Lake (Figure 133). The channel portion of the reach differs from the connecting channel of the previous reach due to the high occurrence of Type 22 shoreline (11 miles). The relief is higher along the channel than in the lake.

Fidler, a lake of low relief, does not exhibit the steep shoreline typical of the lakes in the previous reaches. The bedrock controlled shoreline of the lake contains a glacial till overburden.

In general, the long stretches of convex shoreline are Type 15 (12 miles) while the shorter stretches of promontaries and bays are Types 13 (6 miles) and 14 (3 miles).

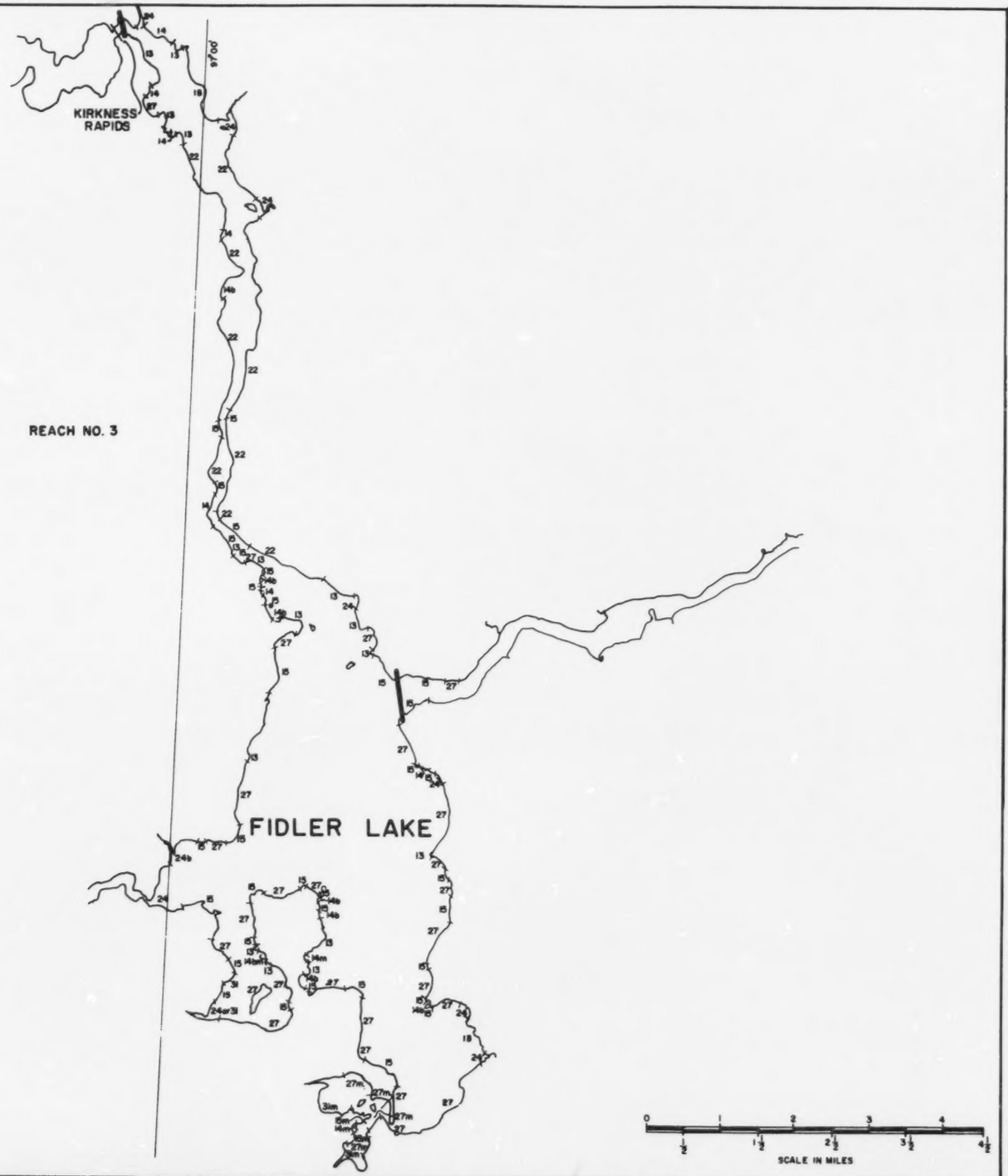
The long sweeping concavities (15 miles) of granular beach were classified as Type 27. The beach material consisting of gravel and cobbles overlaid a clay mantle which in turn covers the bedrock. The beaches are generally wider than those previously described and covered with a similar vegetation.

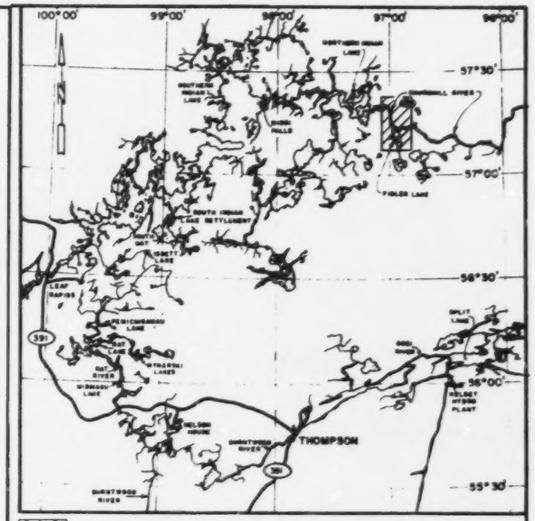
Isolated sections of Type 24 and 31 are evident in the southern portions of the lake. Each consists of approximately 10 and 3 miles respectively.

The beach material varies from boulders and rock to gravel. Most of the water wash zone averaging 200 to 300 feet in width is colonized by willows and grass. This willow border does not extend much below the maximum water level. The water-washed zone exhibiting fine materials is normally covered by grasses up to the water line while coarse material is sparsely colonized.

Bedrock controlled irregularities have a thick deposit of glacial till over them, producing long stretches of convex, Type 15 shorelines as illustrated in the following profile. Long sweeping concavities, classified as Type 27, are low beach type shorelines and consist of gravel and cobbles. These cobbles lie over a clay mantle which in turn lies over bedrock. The backshore is a till bank.

On the river section which enters the northern end of Fidler Lake, these concavities are classified as Type 22 beaches. There is higher local relief here and sand was deposited rather than found in-situ.





= LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
⊥ ⊥	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 133

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
LOWER CHURCHILL RIVER
REACH 3
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED / DATE	APPROVED / DATE
D.S	N.S.	T.M.		
SCALE	DATE	SHEET NO.	FILE NO.	
AS SHOWN	APRIL/74	36 OF 58	61-1-1025	

Reach 4 - Fidler Falls: This reach includes the channel from Fidler to Billard Lake (Figure 134). It is typically a sequence of rapids or falls and pools. Relief of the surrounding terrain at Fidler Lake is low but increases in the downstream direction until a point about two-thirds of the way to Billard Lake. Bedrock shorelines are common and are separated by Type 14 bedrock-controlled stretches. Minor slumping is found on the backshore over this reach and on all shoreline classifications except Type 24.

Bedrock outcroppings are Type 13. The water-washed zone is narrow. The overburden is till containing permafrost and minor slumps may be found on the steep backshore. The backshore vegetation is normally open or closed coniferous forest, mainly Picea mariana with some Larix laricina and occasional Picea glauca. The trees are normally not higher than 30 feet, although better growth may occur on south-facing slopes. There are 26 miles of Type 13 shoreline.

Joining most of the outcrops is 34 miles of Classification 14. These slopes are steeper than the typical case. A boulder and cobble beach rests at the bottom of the till banks. Permafrost contributes to the inevitable slumping. Vegetation density and height is less than the normal for this profile and as for Type 13 the species are less varied.

Near the upstream end, above the first rapids, low moderately drained shorelines exist. The 12 miles of Type 23 differ from the average mainly because of the vegetation, as described for Type 13. The alluvial shoreline is backed by a several foot thickness of glacial till. Melting permafrost again plays a part in the slumping activity of this shoreline. The slumping inevitable occurs on the initial fairly steep rise.

Type 24 shorelines are found in this reach but not in great extent, about 4 miles in all. They occur in embayments at the mouths of small tributaries. The "beach" is of granular material.

Willows may grow to the water with no Carex spp, or Scirpus sp. The backshore rises slowly to the not too distant uplands.

As mentioned before slumping is frequent. Where erosion is active enough and the face of the bank is devoid of vegetation the shoreline has been characterized as Type 25. There are about 2 miles of this shoreline on Reach 4. The vegetation on the uplands is an open coniferous forest, the Picea mariana being no more than 20 feet high. A sparse understory and heavy organic layer is also common on the upland.

Reach 5 - Billard Lake: Reach 5 includes Billard Lake to a point some 16 miles downstream (Figure 134). Very low relief is a trademark of this reach. The low shorelines, Type 22, 24 and 28, constitute most of the riverbank. The river is broad, reasonably shallow and has a cobble bottom. It has a braided nature. Large islands are found in midstream.

Type 22 beaches are common on this reach. A reasonably broad, 20-30 feet, foreshore is common. The riverbed slopes very slowly from the water's edge to the shallow uniform bottom. The backshore, unlike that portrayed in the typical drawing, has a slope similar to the foreshore. Though deciduous shrub dominated immediately behind the beach this zone soon ends

and open or closed coniferous (Picea mariana) forest takes over. The understory is sparse Alnus sp. and Ribes sp.. A heavy Sphagnum spp. ground cover is evident throughout the approximately 14 miles of this shoreline.

There are 12 miles of Type 24 shoreline. Similar to Type 24, but having a much better developed marsh, is Type 28. Although Salix spp. and Alnus sp., are not as dense as on the Rat-Burntwood system, they are still extensive, stretching far into the water and some distance inshore. Six miles of marshes exist on Reach 5.

Occasional stretches of Type 23 are evident. They amount to about six miles in all. They are identical occurrences to those found in the previous reach.

Infrequent outcrops at the lower end of the reach provide about two miles of Type 13 shoreline. As with other profiles in the area, the relief is low. Backshore conditions are similar to local Type 23 banks. No backshore outcrops are evident.

About one-half mile of slumping shorelines, Type 25, are in evidence a few miles below Billard Lake. Relief is less but backshore conditions are similar to those mentioned in the previous reach.

Another minor component, concentrated at the lower end of the stretch being considered, is four miles of Type 14 bedrock-controlled riverscape. In this particular case the backshore appears to rise to an esker. Vegetation differences are not known but aerial observation does not indicate significant variation from that found on Reach 4.

Reach 6 - Billard Rapids: The channel from a point 16 miles below Billard Lake to a point 12 miles further has been characterized as Reach 6 (Figure 134). It embodies the same characteristics as the Reach between Fidler and Billard Lakes. Rapids are perhaps more frequent here and the channel may be slightly more irregular but this only belies a more dominant bedrock shoreline. The major types are 13 (12 miles) and 14 (eight miles). At the upper end, some Type 24 shorelines exist (.4 miles) while at the downstream end variation if offered by Type 25, two miles in extent. No significant differences within types need be noted.

Reach 7 - Upper Canyon: From the lower end of Reach 6 to the head of the Lower Canyon-Portage Chute Rapids lies Reach 7 (Figure 135). The first few miles of it are not unlike the previous reach but for one fact; this is the upstream end of a very long ice-accumulation reach. For the first time we notice extensive ice-scouring action on the shorelines. The reach begins with moderate relief which increases quickly until the riverbanks rise steeply for 200 feet to the uplands. Below the Little Churchill the valley walls are much less steep and the total rise to the uplands is perhaps 50 feet less. Bedrock and boulders line the channel bed although horizontal control is most frequently exercised by alluvium. The overburden throughout this reach is glacial till containing clay, silt, sand and coarser materials. Differences in vegetation between south and north-facing slopes are marked. Southern exposures consist of more and larger Picea glauca. The Picea mariana grows likewise to heights of 50 - 60 feet while on the south banks 30 - 40 feet would be a maximum.

Type 21 dominates the shoreline in Reach 7. Its main characteristic, of course, is the ice-scoured zone of vegetation. At the upper end of this section it extends maybe only five feet above the normal water level, but at the lower end the ice-scoured zone measures up to 30 feet in the vertical. Above the Little Churchill the banks are steep and backshore slumping is frequent. Between the Little Churchill and Portage Chute Rapids the banks have a shallower slope and such activity is uncommon. Vegetation is as shown in the typical profile with the above mentioned, direction-oriented differences. About 106 miles of the riverbanks here are Type 21.

Making up the remaining twelve or so miles of riverbank is Type 13 (five miles) and Type 25 (seven miles). Where the banks are steep, Type 25 is a common shoreline. Permafrost is a major factor in their formation. The slump faces tend to take the shape of cusps and northfacing exposures develop into flatirons. The cliff faces are virtually free of vegetation and the open faces extend right to the upland vegetation.

Reach 8 - Lower Canyon: Reach 8 extends from the head of Portage Chute to the extreme western boundary of the former Tyrrell Sea (Figure 135). Its main characteristic is the Type 12 shoreline, about 22 miles long, which consists of a vertical limestone cliff backed by a smooth rise (till) to the uplands. The Paleozoic limestone lines the bed and banks of the channel. Ice accumulation does not exceed the height of the limestone outcrops on the upper segment, while downstream the limestone dips below the zone of ice accumulation. Here, slumping of the till above the limestone is usual. The slumps, however, do not extend to the uplands. Vegetation is as described in the typical drawing of Type 12.

There are about eight miles of Type 21 separating stretches of bedrock. Slumping on the backshore is of a minor nature, and the slope here, (the Lower Canyon), is less than that found in the Upper Canyon. The uplands, however, are nearly 400 feet above the river and nearly a mile is required to reach that height. Vegetation is of the seasonal steppe below the 45 foot ice-scour line. The backshore is the same as that found on Type 12.

Reach 9 - Long Island: Since entering the region of Paleozoic limestones the river has followed a more or less straight course (Figure 135). This continues except for one irregular stretch until the estuary is reached. The riverbed is limestone, becoming boulders as the estuary is approached. Low water reveals bedrock on the shoreline but at normal levels the river is controlled horizontally by alluvium and marine deposits. The flow is fast throughout but with only one section of rapids.

Type 21 shoreline, amounting to 82 miles in all, not including Long Island, etc., is the most common type. The banks gradually decrease to a height of 40 or 50 feet. As already stated the backshore is composed of marine deposits. Vegetation is somewhat stunted and ranges between an open coniferous forest and a steppe forest. The uplands show frequent frost polygons.

Type 25 accounts for the remaining 17 miles on Reach 9. The base of slumps are often protected by accumulated boulders

but the active slopes extend right up the uplands. The uplands become tundra-like nearer the bay and a heavy peat layer is also characteristic. Permafrost is continuous in this reach.

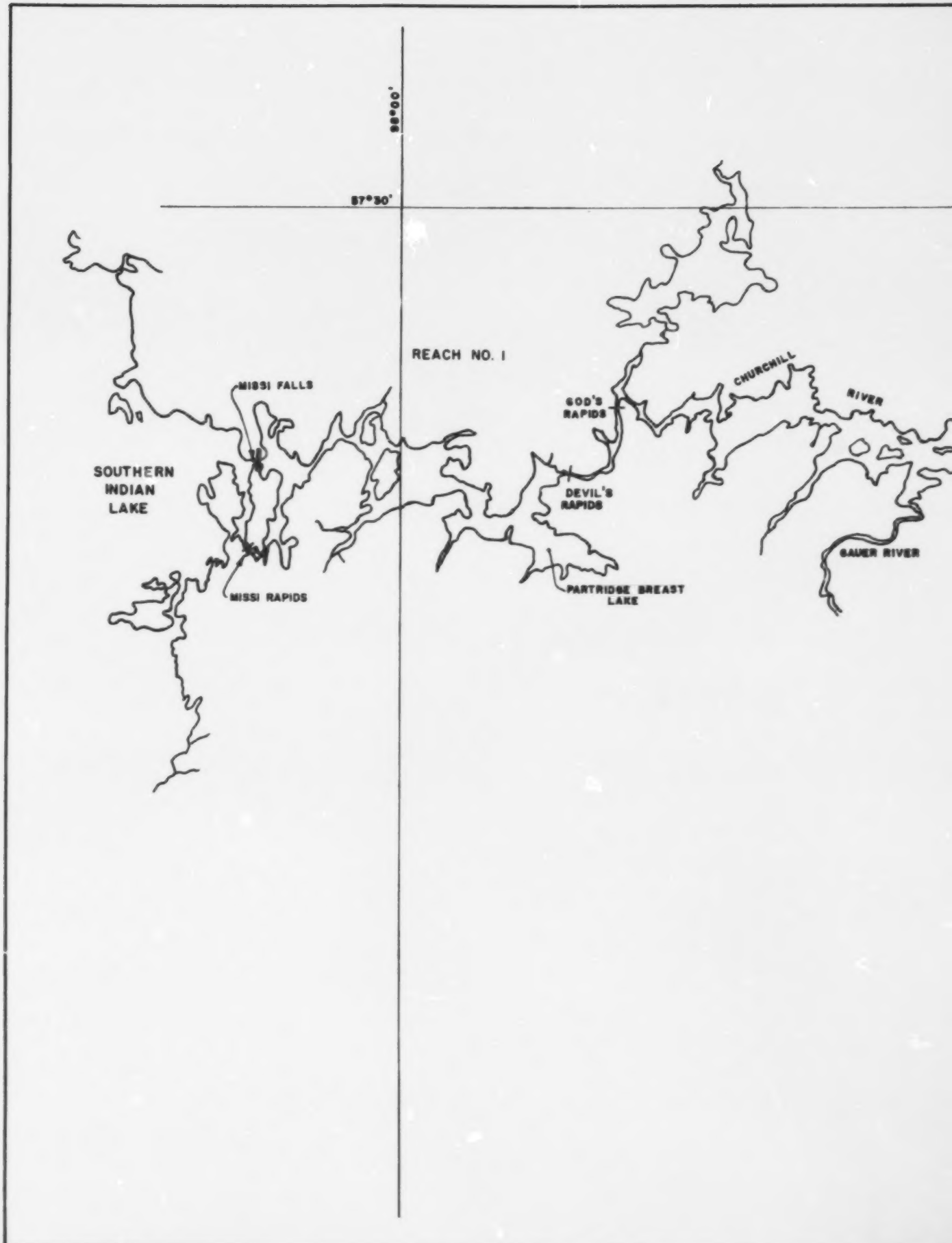
Reach 10 - Long Island to Hudson Bay: The final reach is found in the estuary below Long Island, and extends right to the Bay (Figure 135). The relief is low, similar to that on the reach below Billard Lake. The shorelines are mainly of granular material and slopes are slight. The estuary at the upper end is shallow.

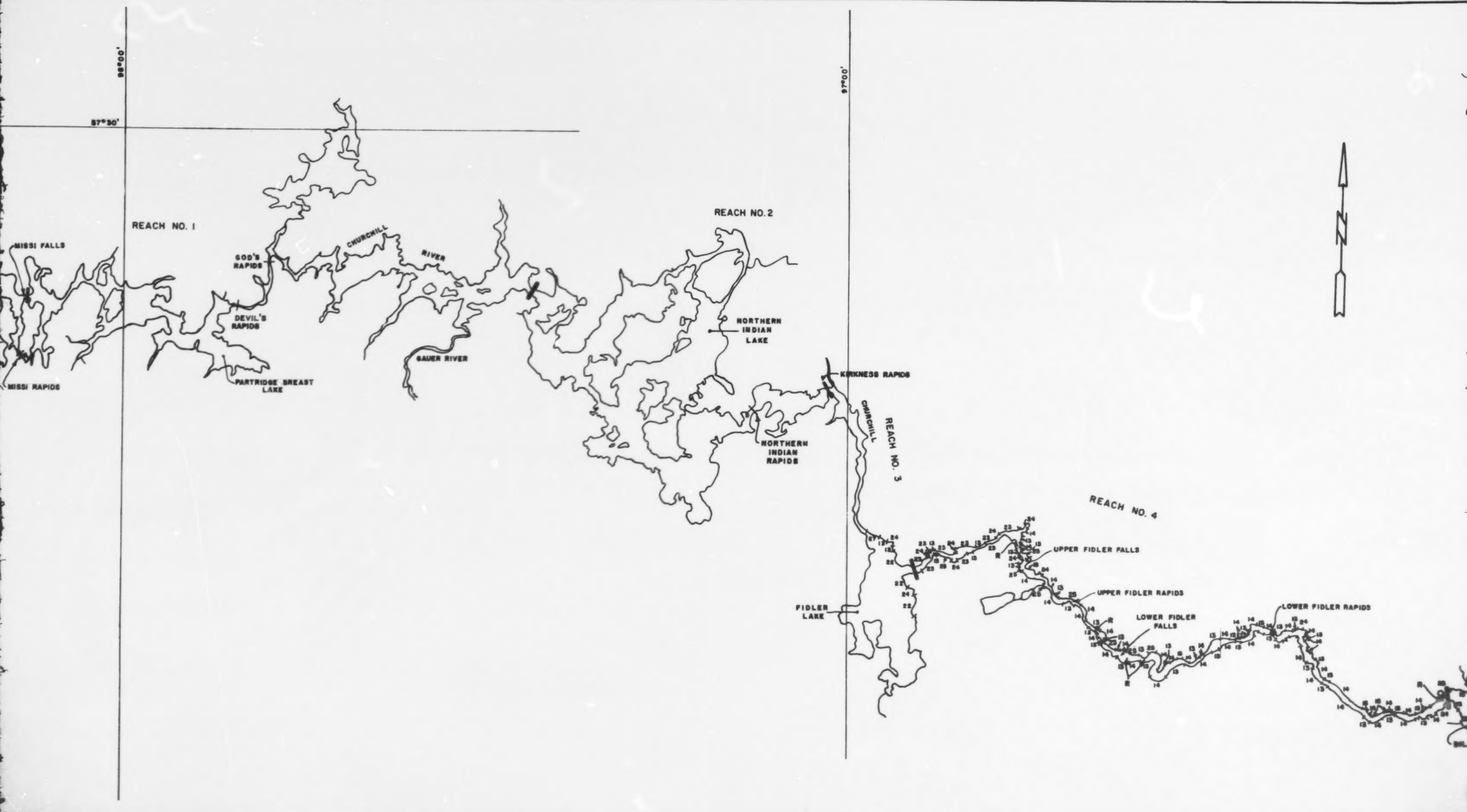
Type 24 is common on the esturary, making up 28 miles of shoreline. It is similar to occurrences below Billard Lake except that the growth is more stunted. A few pot-hole impoundments with associated vegetation are found in the backshore.

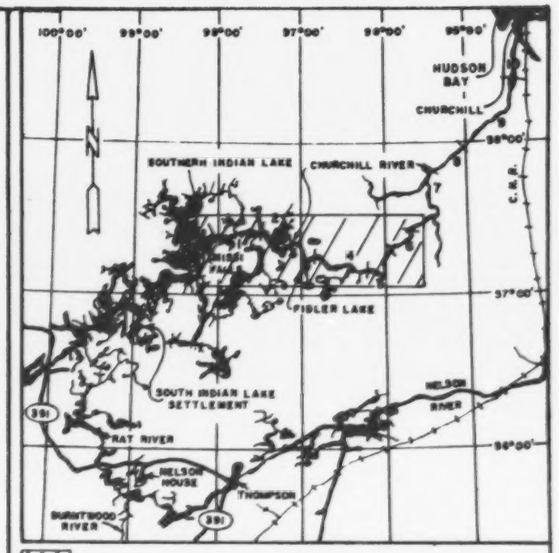
Precambrian sandstones protrude from the marine deposits in the last few miles of the esturary. Tides and wave-action create a wide water-washed zone. The rock is free of growth even above this, until the tundra's heavy peat layer is reached. Trees here consist of dwarfed and sparse Picea mariana growing on a heavy Sphagnum spp. layer. Poor, almost non-existent backshore drainage is characteristic. There are about six miles of exposed bedrock shoreline on this Reach.

Type 28m shoreline accounts for five miles of escuary shore. It sits mainly on granular material. The vegetation is relatively sparse, a few Salix spp, giving way to occasional dwarfed Picea mariana. The shallow shoreline is well dotted with stands of Carex spp.

The last portion of this reach consists of some 22 miles of fen shoreline. The hydrophytes typical of this fen are rooted in the alluvium,


98°00'
97°30'
REACH NO. 1
MISSI FALLS
SOUTHERN
INDIAN
LAKE
MISSI RAPIDS
GOD'S
RAPIDS
DEVIL'S
RAPIDS
PARTRIDGE BREAST
LAKE
CHURCHILL
RIVER
GAUER RIVER


98°00'
97°30'
97°00'
REACH NO. 1
REACH NO. 2
REACH NO. 3
REACH NO. 4
MISSI FALLS
MISSI RAPIDS
GOD'S RAPIDS
DEVIL'S RAPIDS
PARTRIDGE BREAST LAKE
CHURCHILL RIVER
GAUER RIVER
NORTHERN INDIAN LAKE
NORTHERN INDIAN RAPIDS
KIRKNESS RAPIDS
CHURCHILL
FIDLER LAKE
UPPER FIDLER FALLS
UPPER FIDLER RAPIDS
LOWER FIDLER FALLS
LOWER FIDLER RAPIDS
N



LOCATION PLAN

0 20 40 60

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
⊥ ⊥	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

0 4 8 12

SCALE IN MILES

FIG. 134

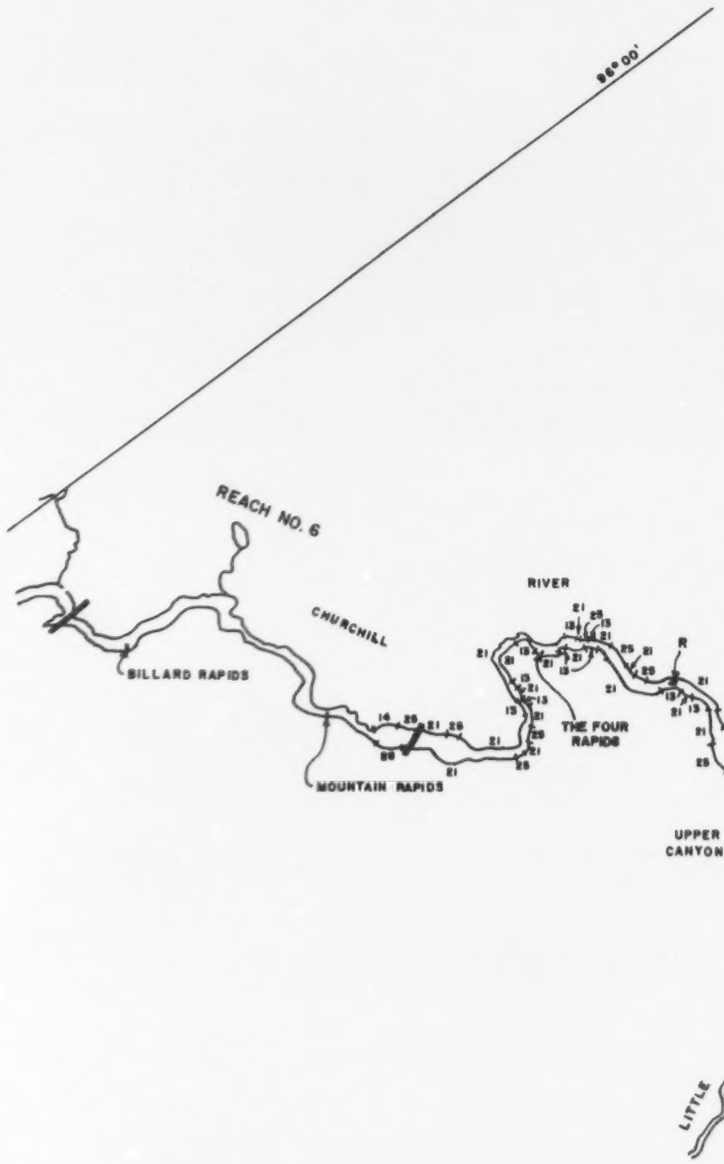
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA–MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

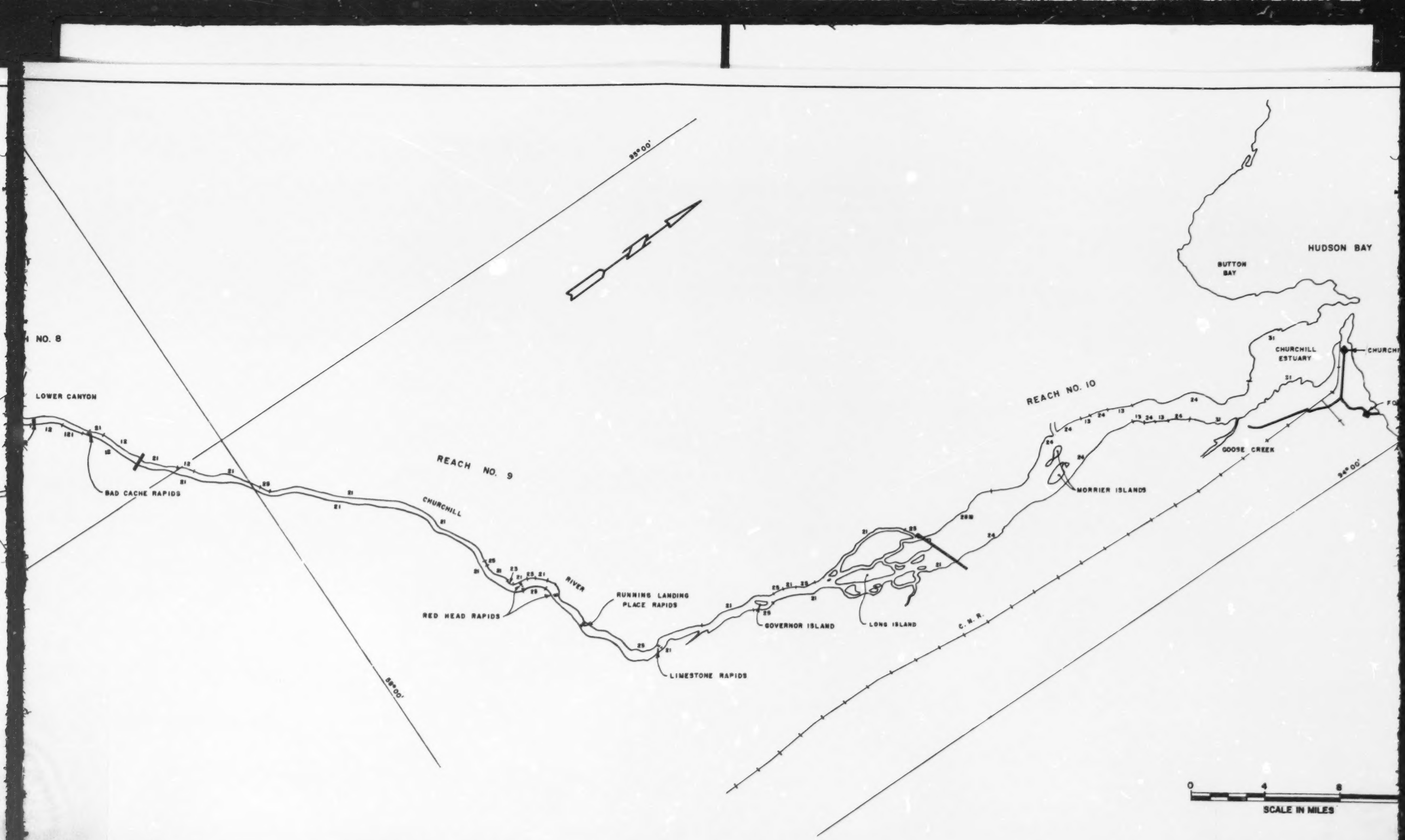
PHYSICAL IMPACT STUDY

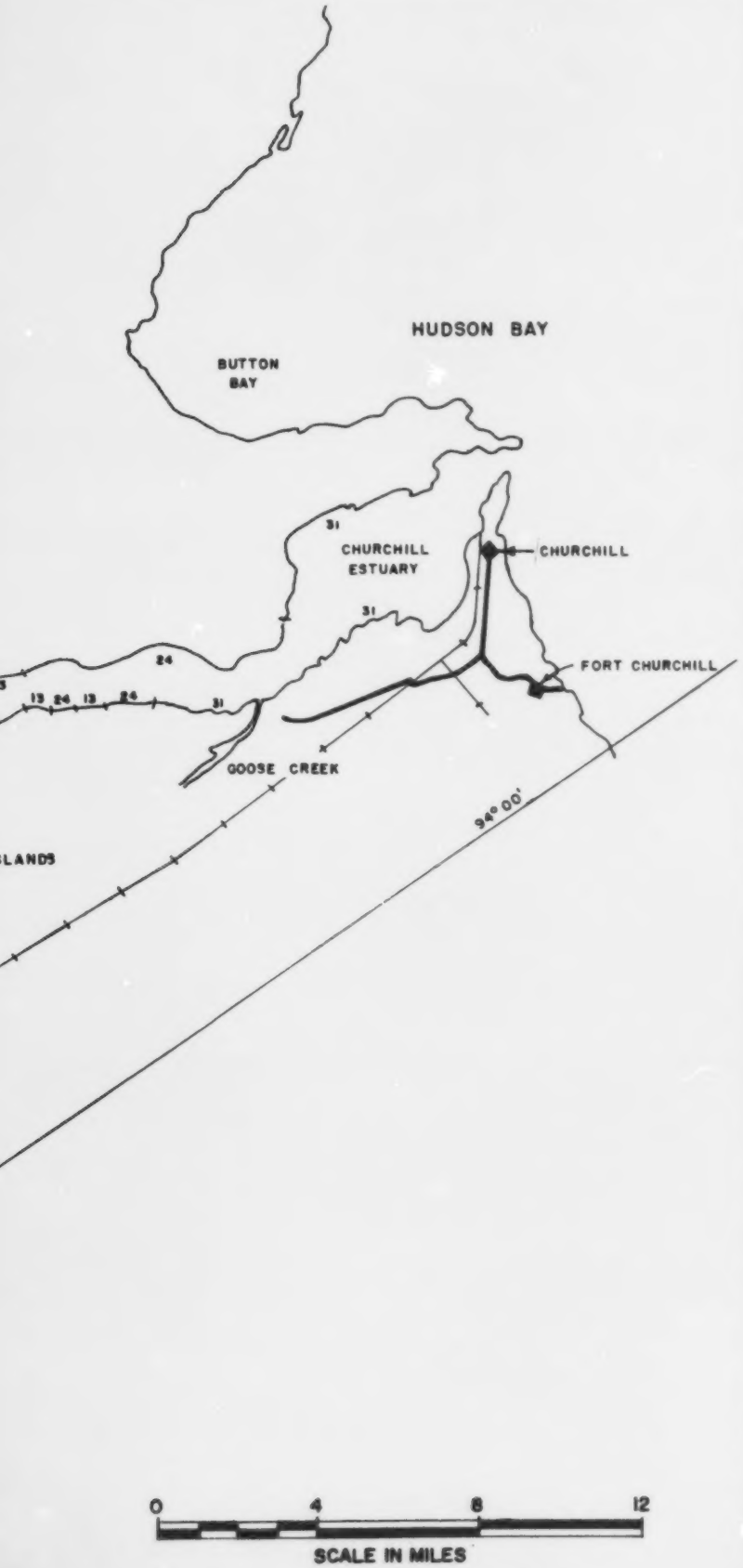
LOWER CHURCHILL RIVER
REACHES 1 TO 7
SHORELINE AND INUNDATED AREA CLASSIFICATION

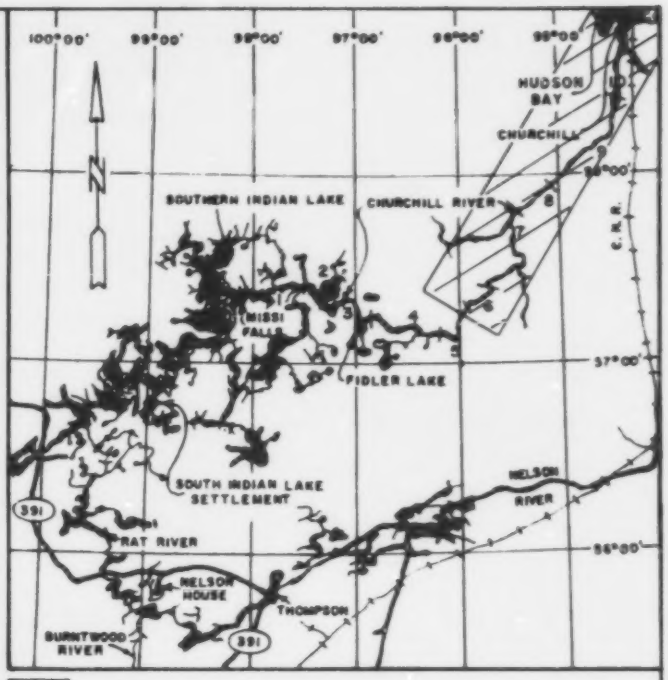
PREPARED	DRAWN	CHECKED	SUBMITTED DATE	APPROVED DIR.
T. M.	N. S.	F. P.		
SCALE	DATE	SHEET NO.	FILE NO.	
AS SHOWN	APRIL/76	37 of 38	61-1-1088	


REACH NO. 6
RIVER
CHURCHILL
BILLARD RAPIDS
MOUNTAIN RAPIDS
THE FOUR RAPIDS
UPPER CANYON
LITTLE
BEAVER
RIVER
REACH NO. 7
SWALLOW RAPIDS
RIVER
CHURCHILL
LITTLE

REACH NO. 8
PORTAGE CHUTE RAPIDS
LOWER CANYON
BAD CACHE RAPIDS


H NO. 8
LOWER CANYON
BAD CACHE RAPIDS
REACH NO. 9
CHURCHILL
RIVER
RED HEAD RAPIDS
RUNNING LANDING
PLACE RAPIDS
LIMESTONE RAPIDS
GOVERNOR ISLAND
LONG ISLAND
REACH NO. 10
CHURCHILL
ESTUARY
GOOSE CREEK
MORRIER ISLANDS
BUTTON
BAY
HUDSON BAY
C. N. R.
93° 00'
89° 00'
94° 00'
0
4
8
SCALE IN MILES





= LOCATION OF MAP

LOCATION PLAN

0 20 40 60

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
⊥ ⊥	SEDGE COMMUNITIES
Xx Xx	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED

FIG. 135

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

LOWER CHURCHILL RIVER

REACHES 6 TO 10

SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED
T. M.	N.S.	F. P.	DATE	DATE

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	APRIL/74	38 OF 58	61 - 1 - 1025

6.5.2 WATER LEVELS AND FLOWS - MISSI FALLS TO HUDSON BAY: Figure 136 shows the natural and regulated maximum, minimum and mean monthly discharges at Missi Falls. Discharges in general will be greatly reduced by diversion. Future maximum monthly discharge (exceeded on the average one month in twenty years) will be 55,500 cfs. compared to the natural maximum of 80,000 cfs. Figure 137 shows the approximate duration curve of all monthly discharge values, developed from the averaged monthly curves. Discharges greater than 55,500 cfs and as great as 74,000 cfs will be possible with regulation, but will occur rarely. For example, monthly discharges of 55,500 cfs or greater will occur on the average during only one month in 200, or once in twenty years. Monthly discharges greater than 65,000 cfs will occur during one month in 400 or once in 33 years.

In the same way, extreme low values will be drastically reduced by regulation, from a natural minimum of 23,000 cfs to a regulated minimum of 500 cfs. Extremely low values will be very common. For example, a discharge of 10,000 cfs or less will occur during half of the summer months (Figure 137) and in nine out of ten winter months. Over both seasons, half of all months will have a discharge less than 2,500 cfs. The average monthly discharge with regulation will be 8,900 cfs as compared to a natural mean of 36,000 cubic feet per second.

The seasonal distribution of discharges will be only slightly changed, with highest levels occurring in early summer, possibly one or two months earlier than natural. Discharges then drop to mid-to late winter lows.

Monthly fluctuations will be considerably increased with regulation. Monthly rises in discharge will generally be experienced during the months of January through June. These rises will normally be less than 5,000 cfs in January, February, March and April, and less than 20,000 cfs in May and June. Maximum rises, greater than 40,000 cfs will occur possibly once in 20 years in June and once in 50 years in May. Falling discharges will dominate July, August and September. These drops will generally be less than 20,000 cfs but will be as great as 30,000 cfs or more on rare occasions (one month in 50 years). October, November and December will experience falling discharges nearly as frequently as rising discharges with the greater rises (as great as 30,000 cfs) in October and the greater drops (as great as 20,000 cfs) in November and December.

The various discharge parameters at Missi Falls are outlined in Table 39.

These releases at Missi Falls are altered significantly in downstream reaches by two factors:

1. Storage in the four downstream lakes will have a moderating effect on extreme discharges. Peak flows are considerably reduced and low flows slightly increased.

2. Local runoff to the Churchill River will increase discharges. This effect increases in the downstream direction.

Discharges from Billard Lake are therefore somewhat different from releases at Missi Falls. Figure 138 and the following table outline the natural and regulated discharge regimes at the outlet of Billard Lake. These flows can be considered representative for at least the upper portion of the river below Billard Lake. (See Table 40).

Between Billard Lake and Churchill, the Churchill River discharge is further modified by two factors:

1. Local inflow will increase discharges

somewhat. This will be especially important during low flow periods.

2. Possible temporary reduction of winter flow to zero by ice jamming with regulation has been suggested (Reference 23). Since the future winter regime of the river is not well understood at this time, this effect has been neglected.

Monthly inflow to the Lower Churchill River below Billard Lake has been estimated. The calculated minimum, maximum and mean local inflows for each month are included in Figure 139, showing a long-term average inflow of 3,500 cfs. Minimum, median and maximum Churchill River flows at Churchill were estimated by simply adding the respective values of local inflow to discharges at Billard Lake, and are outlined in Figure 140 and in Table 41.

It can be appreciated by comparing these figures with Missi Falls that discharges at Missi Falls will be significantly increased by local runoff before reaching Churchill, and that this effect will be especially important in periods of low flow.

On the Lower Churchill River system, winter ice conditions are important in the water level regime. In many places winter levels are higher than maximum summer levels (Reference 22) even though the discharge is lower. For the four downstream lakes (Partridge Breast, Northern Indian, Fidler and Billard) the outlets remain under open water conditions or are little affected by ice throughout the winter. Winter water levels for these lakes are, therefore, determined from open water rating curves at the outlets. Winter levels in the reach from Billard Lake to Hudson Bay are largely determined by ice conditions. Surcharges over summer levels by as much as 50 feet have been reported in the Bad Cache to Portage Chute Rapids Reach (Reference 22), and must be considered in the water level regime.

Water levels in the four downstream lakes in the Churchill River system are determined primarily by the discharges at Missi Falls and local inflows. Hence, all four lakes display similar characteristics. (Figures 141 to 144). In the natural state, high water levels occur during late summer and low levels during late winter. Regulated levels will be considerably lower than natural levels, but will display a similar seasonal variation of summer highs and winter lows. The net result will be a reduction in mean water level of nearly 10 feet. Peak levels, as defined for the purposes of this study, will be decreased by approximately 4 to 7 feet. The following tables summarize the natural and regulated water level regimes for the four lakes. (See Tables 42, 43, 44 and 45).

Water levels and depths in the channel sections of the Lower Churchill River system are summarized in Table 46. Water depths as quoted in the Table are determined for open water conditions for minimum, mean and maximum discharges. This roughly represents the summer water level regime.

On the Churchill River, however, highest levels in many reaches presently occur in the winter, when flows are reduced. This is a result of surcharging by ice formation on the river to levels considerably higher than open-water conditions. The corresponding surcharge with the vastly reduced winter flows following regulation cannot be accurately estimated at this time, so winter conditions have not been included in the Table. Winter ice effects have been discussed by Newbury (Reference 22) and are outlined below for the various reaches in the table.

1. Partridge Breast Lake to Northern Indian Lake (Gods Rapids):

Natural - open water exists throughout the winter.

Regulated - a competent ice cover will form early in the winter. Winter levels will be only slightly greater than corresponding open water levels, and will be less than peak summer levels.

2. Northern Indian Lake to Fidler Lake:

Natural - some ice accumulation occurs between Fidler Lake and Kirkness Rapids. Winter levels are within the natural summer range.

Regulated - river icing is not considered serious.

3. Fidler Lake to Billard Lake:

Natural - intermittent ice cover forms from Fidler Lake to Upper Fidler Falls, with little effect on water levels. Open water exists throughout the winter from Upper Fidler Falls to Lower Fidler Falls. Accumulation from there to Billard Lake causes a surcharge of several feet.

Regulated - stable ice cover will form and icing is not considered serious.

4. Billard Lake to Little Churchill River:

Natural - stationery ice cover forms early in the season from Billard Lake to Billard Rapids, with levels at open water levels. Open water is maintained from Billard Rapids to Mountain Rapids. A surcharge of up to 10 feet occurs in a two mile stretch of the lower Mountain Rapids. The reach from The Fours Rapids to the Little Churchill River (16 miles) is subjected to ice surcharges of 10 to 15 feet in the upstream sections and 20 to 30 feet in downstream areas.

Regulated - shallow depths of flow may cause icing in the Mountain Rapids area and between The Fours Rapids and the mouth of the Little Churchill River. All other areas in this section will probably attain a stable ice cover with little surcharge over open water conditions.

5. Little Churchill River to Hudson Bay:

Natural - severe surcharge by ice occurs from Swallow Rapids to the mouth. This surcharge amounts to 20 feet at Red Head Rapids, increasing to 50 feet from Bad Cache Rapids to above Portage Chute Rapids. Lesser surcharges occur from there to Swallow Rapids.

Regulated - ice accumulations of 15 to 20 feet are expected throughout most of this length.

TABLE 39

CHURCHILL RIVER FLOWS AT MISSI FALLS

	Natural	Regulated	Change
Minimum	23,000 cfs (Feb to May)	500 cfs (May, June, Sept, Oct)	-22,500 cfs
Mean	36,000 cfs	8,900 cfs	-27,100 cfs
Maximum	80,000 cfs (July)	55,500 cfs (June)	-24,500 cfs
Long-term range	57,000 cfs	55,000 cfs	- 3,000 cfs
Maximum monthly fluctuation			
rise	≤20,000 cfs (May June, July)	40,000 cfs (May, June)	
drop	≤20,000 cfs (Aug, Sept, Oct)	≤40,000 cfs (Sept)	

TABLE 40

CHURCHILL RIVER FLOWS AT BILLARD LAKE OUTLET

	Natural	Regulated	Change
Minimum	24,200 cfs (April, May)	1,900 cfs (May)	-22,300 cfs
Mean	37,400 cfs	10,600 cfs	-26,800 cfs
Maximum	76,000 cfs (Aug)	48,700 cfs (July)	-27,300 cfs
Long-term range	51,800 cfs (Aug)	46,800 cfs (July)	- 5,000 cfs
Maximum monthly fluctuation			
rise	≤20,000 (June, July)	≤40,000 cfs (May, June)	
drop	≤10,000 cfs (Aug to March)	≤30,000 cfs (Sept., Nov)	

TABLE 41

CHURCHILL RIVER FLOWS AT CHURCHILL

	Natural	Regulated	Change
Minimum	24,200 cfs (May)	1,900 cfs (May)	-22,300 cfs
Mean	40,900 cfs	14,100 cfs	-26,800 cfs
Maximum	86,000 cfs (Aug)	58,600 cfs (June)	-27,400 cfs
Long-term range	61,800 cfs	56,700 cfs	- 5,100 cfs
Open water mean	44,600 cfs	20,300 cfs	
Winter mean	37,200 cfs	8,000 cfs	

TABLE 42

PARTRIDGE BREAST LAKE LEVELS

	Natural	Regulated	Change
Minimum	800.5 (May)	788.4 (June)	-12.1 feet
Mean	803.5	793.7	- 9.8 feet
Maximum	810.7 (July)	807.0 (June)	- 3.7 feet
Long-term range	10.2 feet	18.6 feet	+ 8.4 feet
Maximum monthly fluctuation			
rise	$\leq$ 6 feet (June)	8+ feet (May, June)	
drop	$\leq$ 4 feet (Sept, Oct)	8+ feet (Sept, Nov)	

TABLE 43

NORTHERN INDIAN LAKE LEVELS

	Natural	Regulated	Change
Minimum	770.0 (May)	759.0 (May)	-11.0 feet
Mean	774.0	763.7	-10.3 feet
Long-term range	783.2 (Aug)	777.4 (June, July)	- 5.8 feet
Maximum monthly fluctuation			
rise	$\leq$ 6 feet (June, July)	8+ feet (May, June)	
drop	$\leq$ 4 feet (Jan, Sept)	8+ feet (Nov)	

TABLE 44

FIDLER LAKE LEVELS

	Natural	Regulated	Change
Minimum	756.5 (Apr, May)	747.3 (May)	-9.2 feet
Mean	759.6	751.2	-8.4 feet
Maximum	767.1 (July)	762.3 (July)	-4.8 feet
Long-term range	10.6 feet	13.0 feet	+2.4 feet
Maximum monthly fluctuation			
rise	≤ 6 feet (June)	8+ feet (May, June)	
drop	≤ 2 feet (Sept to Mar)	≤ 8 feet (Nov)	

TABLE 45

BILLARD LAKE LEVELS

	Natural	Regulated	Change
Minimum	618.8 (Apr, May)	609.7 (May)	-9.1 feet
Mean	622.6	613.9	9.0 feet
Maximum	633.0 (Aug)	626.4 (July)	-6.6 feet
Long-term range	14.2 feet	16.7 feet	+2.5 feet
Maximum monthly fluctuation			
rise	≤ 8 feet (June)	8+ feet (May, June)	
drop	≤ 4 feet (Sept to Mar)	8+ feet (Nov)	

TABLE 46

DEPTH OF FLOW IN THE LOWER CHURCHILL RIVER CHANNEL WITH VARIOUS DISCHARGES

	Distance (miles)	MINIMUM FLOW Natural	MINIMUM FLOW Regulated (Feet)	Change	MEAN FLOW Natural	MEAN FLOW Regulated (Feet)	Change	PEAK FLOW Natural	PEAK FLOW Regulated (Feet)	Change	RANGE Minimum to Maximum to Ft. Natural	RANGE Minimum to Maximum to Ft. Regulated
Partridge Breast Lake to Gods Rapids	3½	19 to 44 (26)	4 to 27 (14)	-12	24 to 50 (34)	14 to 34 (18)	-16	33 to 64 (45)	29 to 58 (39)	-6	19	25
Northern Indian Lake to Fidler Lake	12	15 to 36 (21)	4 to 28 (11)	-10	18 to 40 (23)	12 to 33 (17)	- 6	21 to 50 (32)	18 to 44 (29)	-3	11	18
Fidler Lake to Billard Lake	38	No information available										
Billard Lake to Little Churchill River	52	9 to 48 (20)	2 to 36 (10)	-10	12 to 52 (24)	7 to 44 (16)	- 8	18 to 59 (32)	14 to 55 (27)	-5	12	17
Little Churchill River to Little Beaver River	24	7 to 23 (13)	2 to 12 (7)	- 6	9 to 29 (17)	5 to 17 (11)	- 6	15 to 39 (23)	12 to 33 (20)	-3	10	13
Little Beaver River to Long Island	55	7 to 16 (10)	2.3 to 7 (4)	- 6	9 to 19 (13)	6 to 12 (8)	- 5	11 to 26 (18)	10 to 21 (15.0)	-3	8	11

NOTES:

1. Water depths are based on rating curves and river profiles contained in a report on "The Effects of Diversion on the River Regime of the Lower Churchill River" Water Resources Branch, June 1971.
2. Depths are taken at the deepest part of the cross-section.
3. Upper values in the table are the range of depths are various locations at the given discharge, lower values (in parenthesis) are means for the reach.
4. All depths are approximate only.
5. Data for the Little Beaver to Long Island reach are based on limited information.
6. Depths are based on open-water rating curves. For winter conditions, see text.

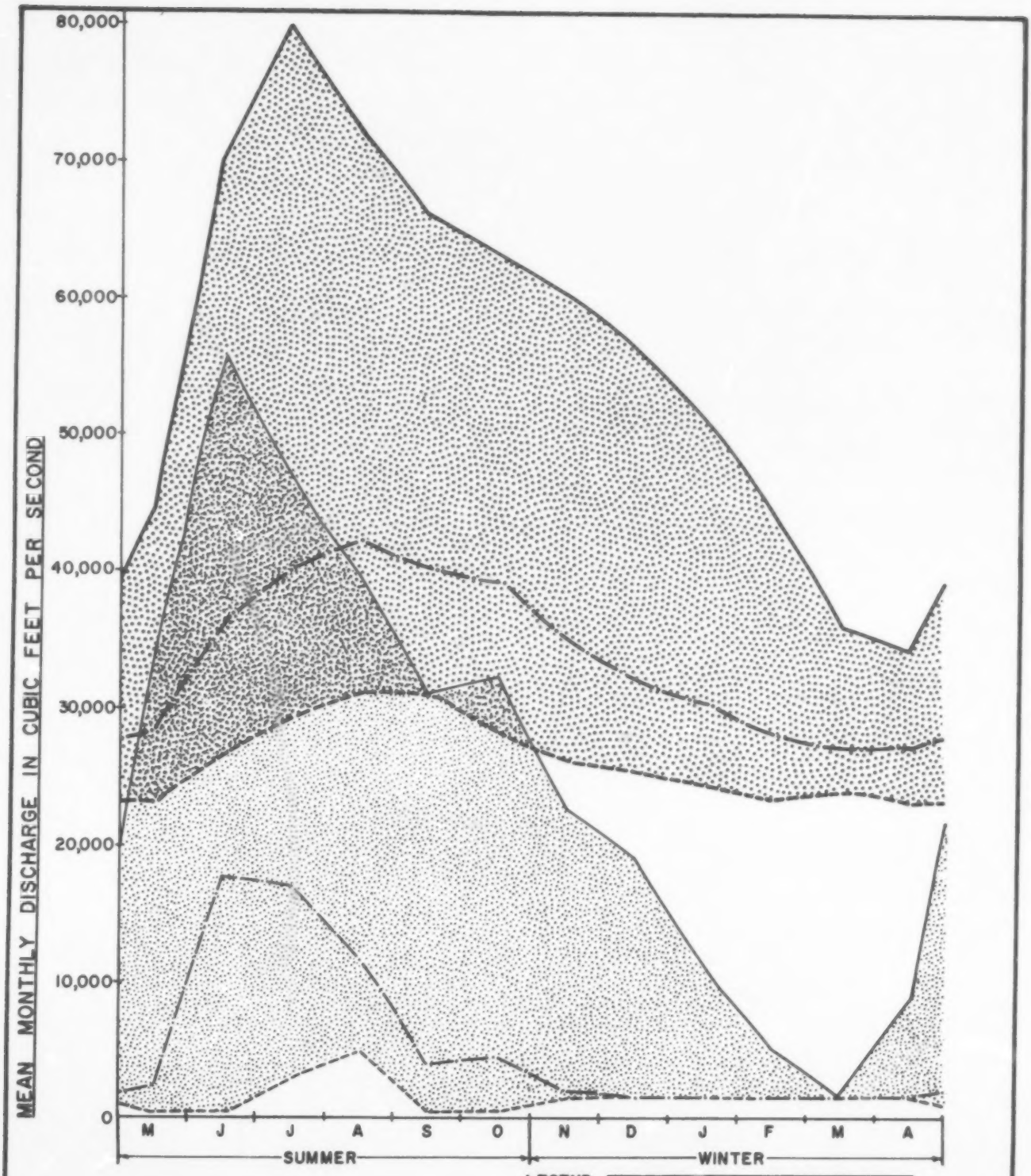


FIG. 136

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

DISCHARGES AT MISSI FALLS

DESIGNED L.B.	DRAWN S.P.	CHECKED F.P.	SUBMITTED J. Perrault	DATE	APPROVED J. Marsden	DATE	SCALE AS SHOWN	DATE JAN/74	SHEET 39 OF 58	FILE NO. 61-1-1025

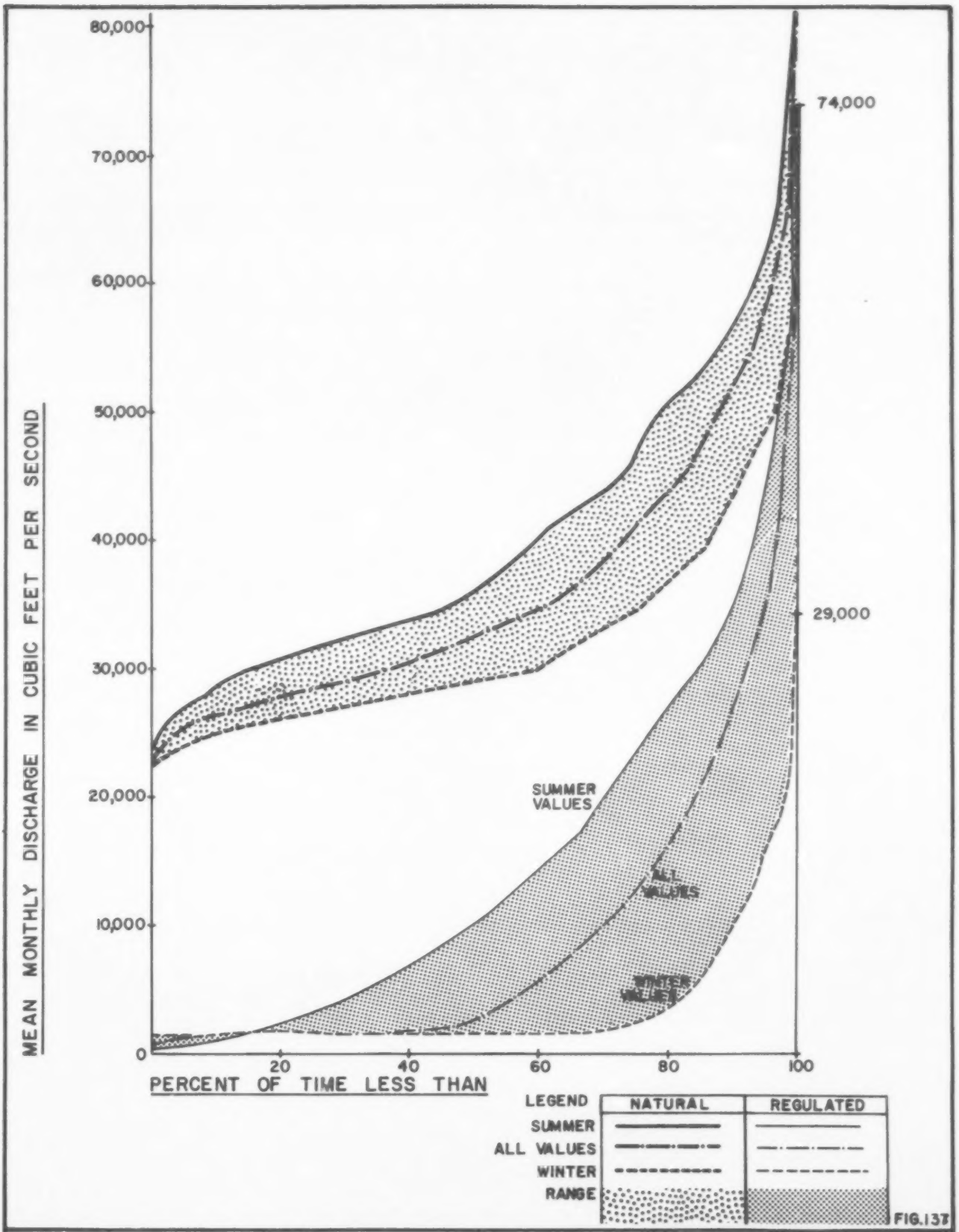


FIG. 137

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

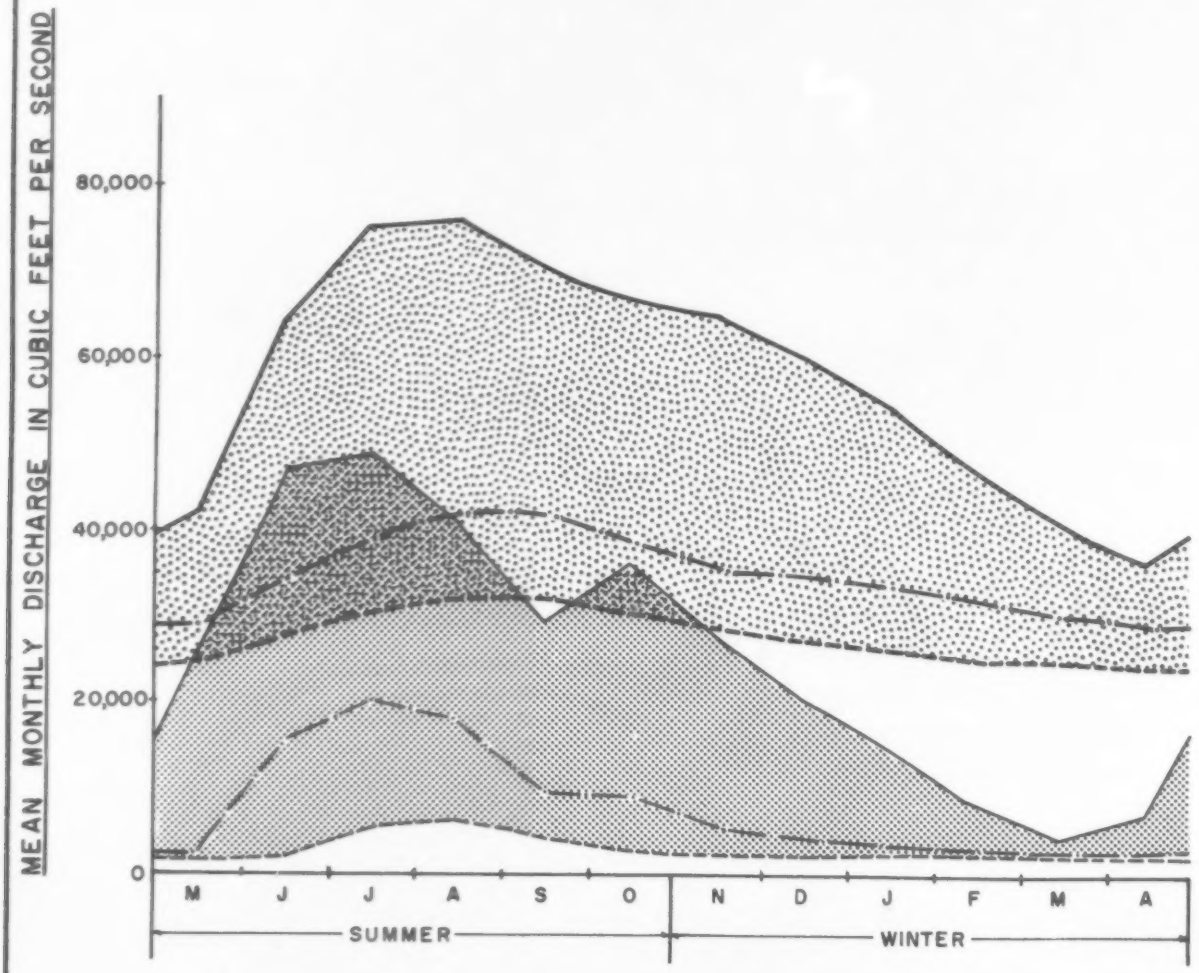
CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

DURATION CURVE OF RELEASES AT MISSI FALLS

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
L.B.	S.P.	DATE	DATE	AS SHOWN	JAN./74	40 OF 58	91-1-1025
	CHECKED F.P.						



LEGEND	NATURAL	REGULATED
MAXIMUM		
MEDIAN		
MINIMUM		
RANGE		

FIG. 138

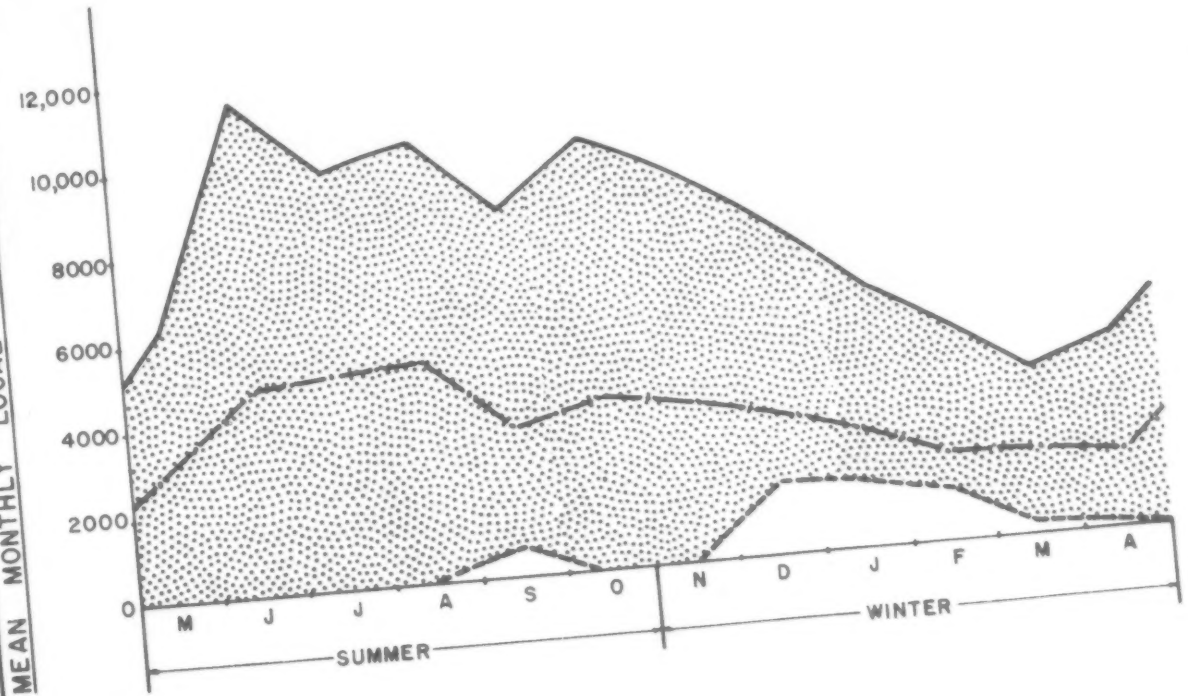
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
DISCHARGES FROM BILLARD LAKE

PREPARED	DESIGN E.P.	SUBMITTED	DATE
L.S.	CHECKED E.P.		

SCALE AS SHOWN | DATE JAN/74 | SHEET 41 OF 58 | FILE NO. 61-1-1025



LEGEND — NATURAL

MAXIMUM

MEDIAN

MINIMUM

RANGE

FIG. 139

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA-MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

LOCAL INFLOW TO THE LOWER CHURCHILL R.

BILLARD LAKE TO HUDSON BAY

PREPARED	DRAWN S.P.	SUBMITTED	DATE
L.B.	CHECKED F.P.		

SCALE AS SHOWN | DATE JAN/74 | SHEET 42 OF 58 | FILE NO. 61-1-1025

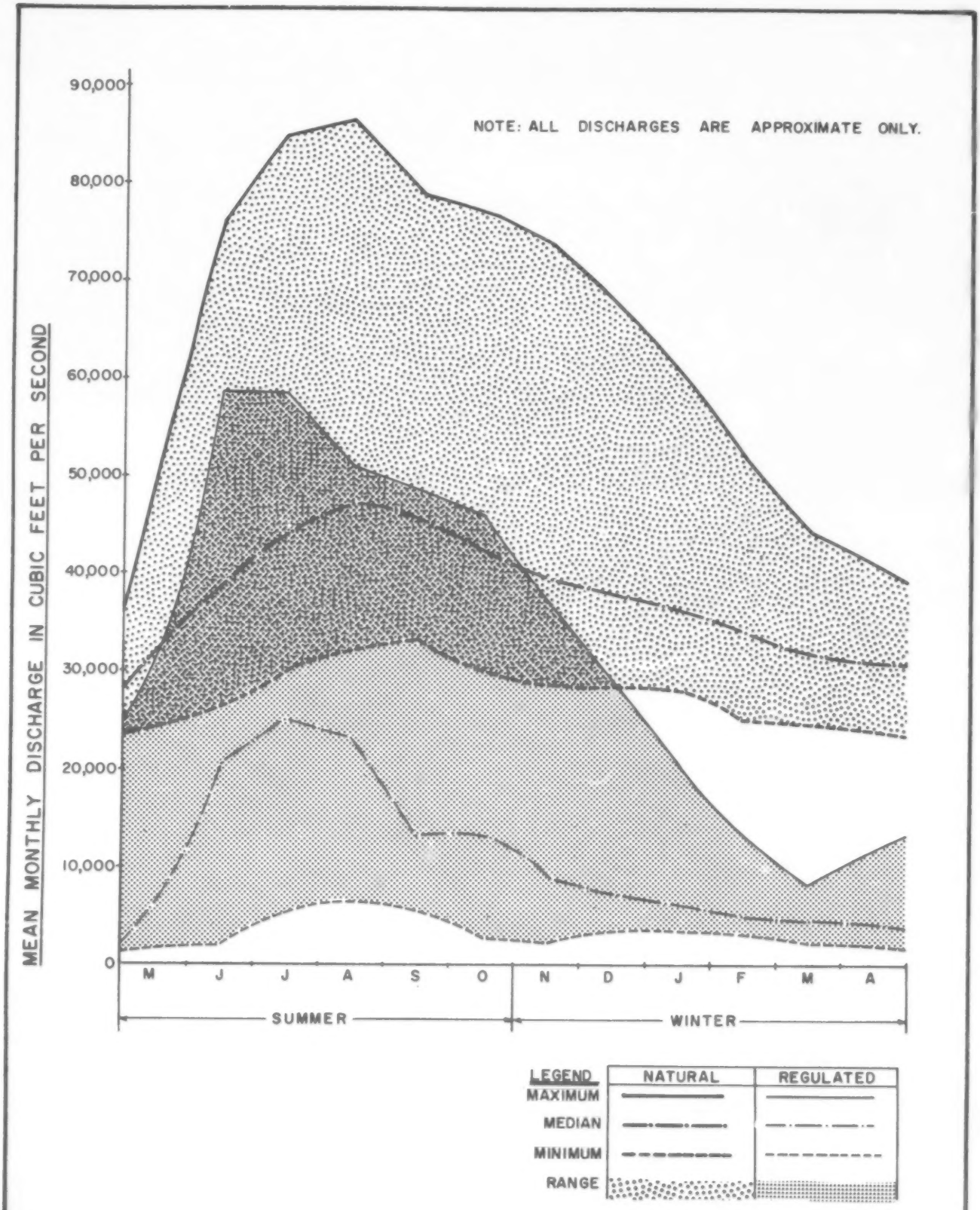


FIG. 140

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
DISCHARGES IN THE CHURCHILL RIVER AT CHURCHILL

L.D.	DESIGNED E.P. / DRAWN F.P.	SUBMITTED DATE	APPROVED DATE	SCALE AS SHOWN	DATE JAN/74	SHEET 43 OF 58	FILE NO. 61-1-1028

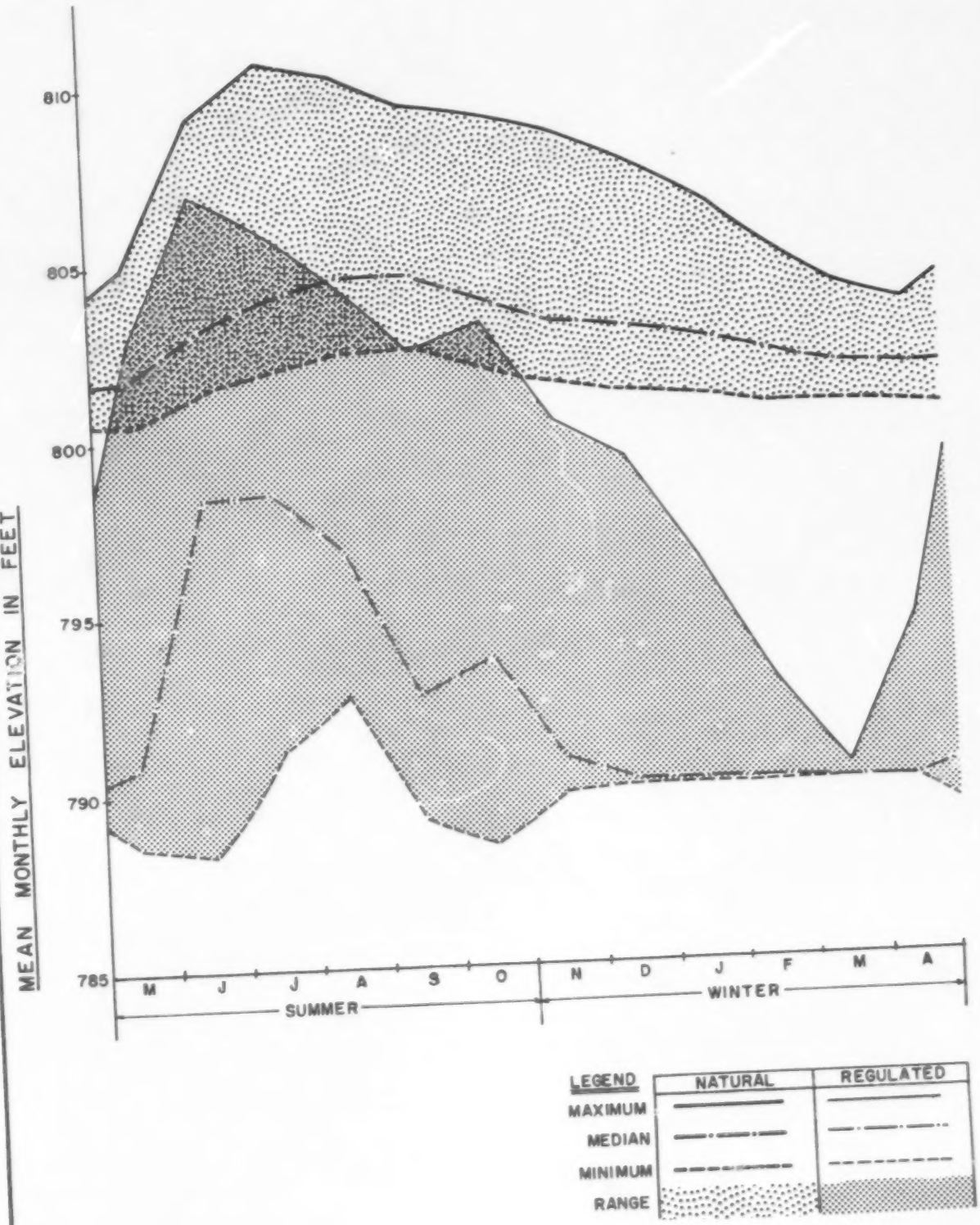


FIG. 141

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY

WATER SURFACE ELEVATIONS AT PARTRIDGE BREAST LAKE

PREPARED	DRAWN	CHECKED	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
L.B.	S.P.	F.P.	DATE	DATE	AS SHOWN	JAN/74	44 OF 58	61-1-1025

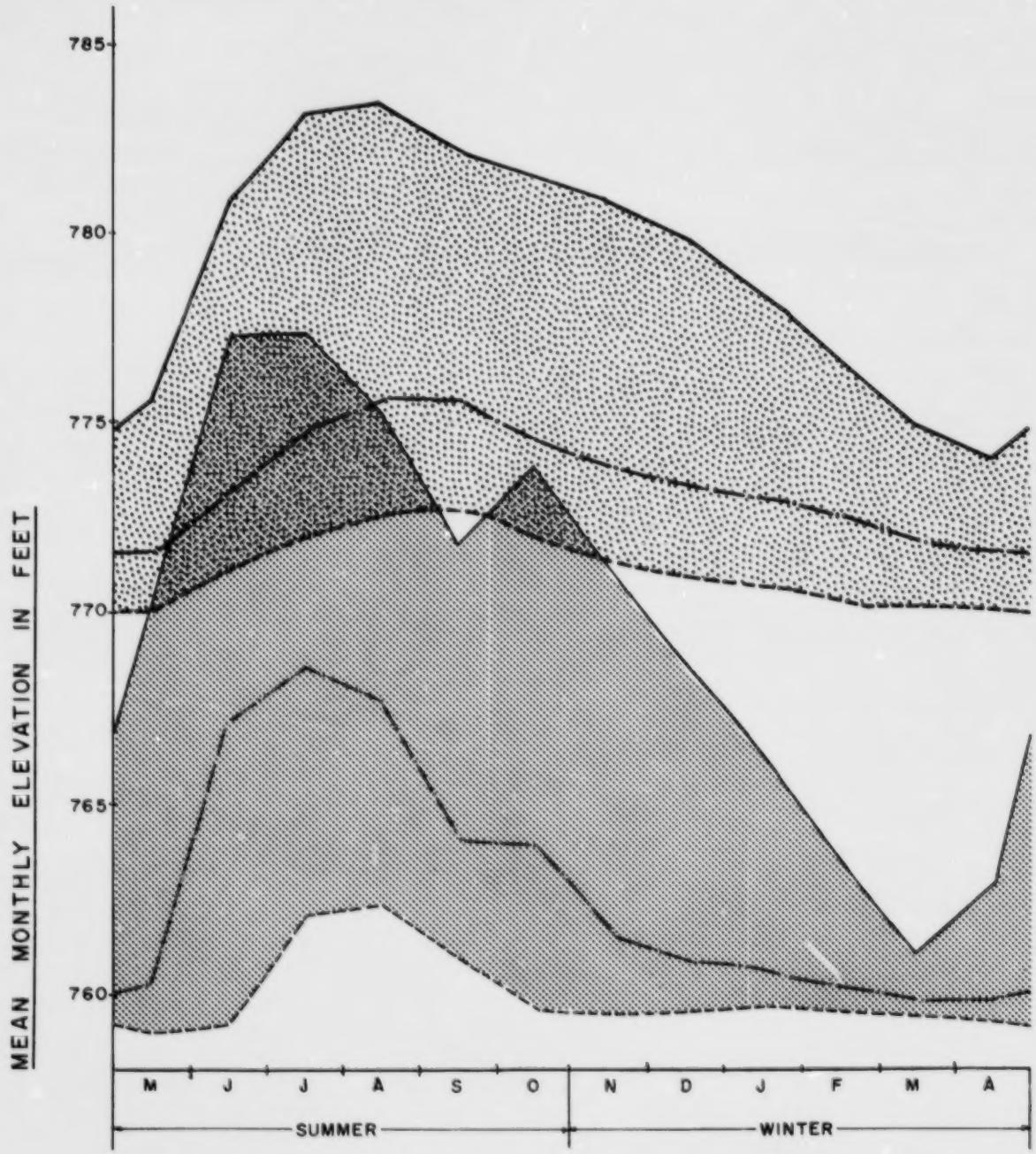


FIG. 142

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

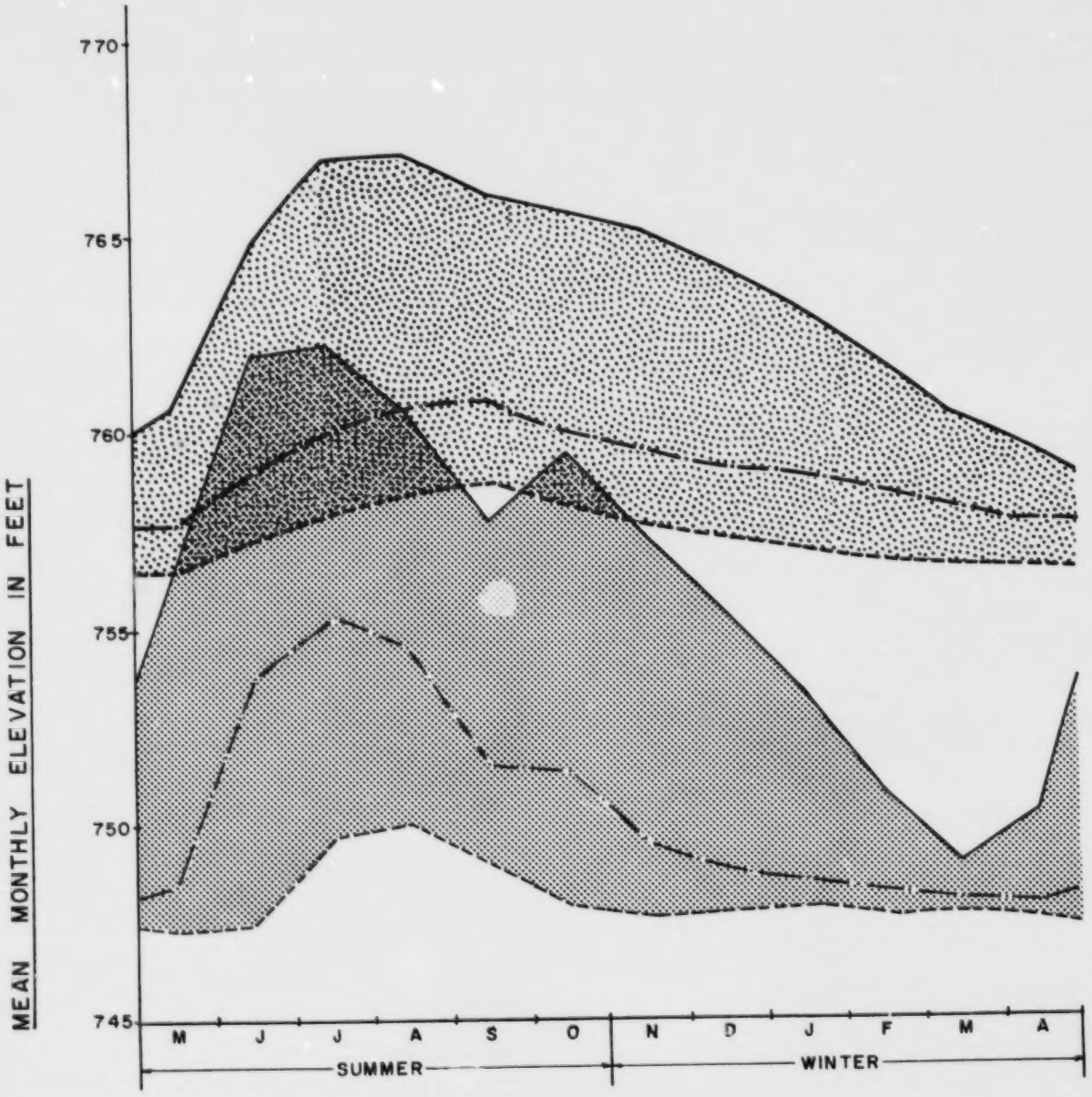
CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSONS RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS AT NORTHERN INDIAN LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.	DATE	DATE
	CHECKED F.R.		

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN/74	45 OF 58	61 - 1 - 1025



LEGEND	NATURAL	REGULATED
MAXIMUM	———	———
MEDIAN	—·—·—	—·—·—
MINIMUM	- - - -	- - - -
RANGE	▒▒▒	▒▒▒

FIG. 143

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS
AT FIDLER LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.	DATE	DATE
	CHECKED F.P.		

SCALE AS SHOWN | DATE JAN/74 | SHEET 46 OF 58 | FILE NO. 81-1-1025

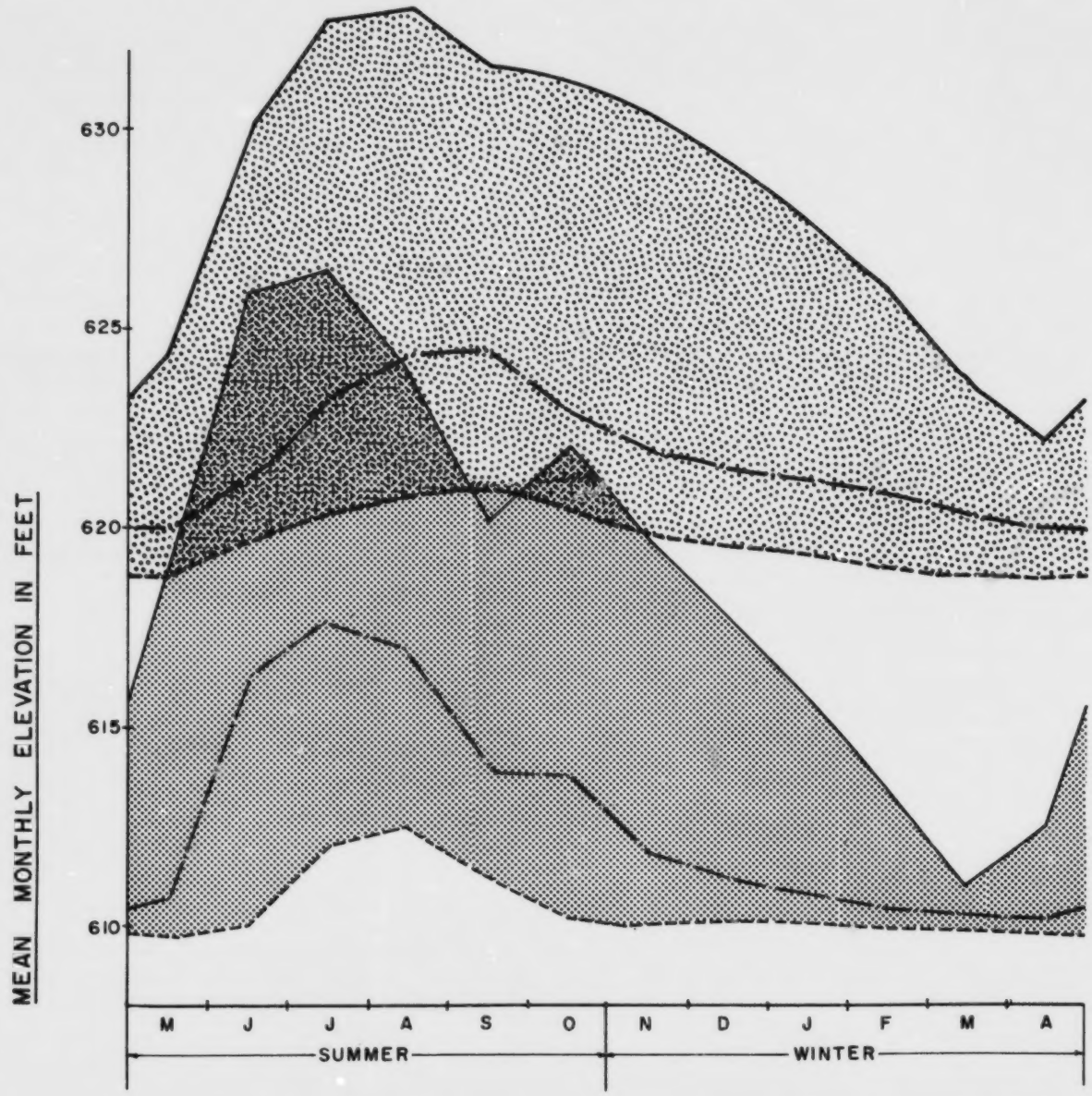


FIG. 144

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS AT BILLARD LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
L.B.	S.P.	DATE	DATE	AS SHOWN	JAN/74	47 OF 58	61-1-1025
	CHECKED F.P.						

6.5.3 IMPACTED STATE CONDITIONS - MISSI FALLS TO HUDSON BAY: The impact on the Lower Churchill River is one of lower water levels due to the diversion of the major volume of Churchill River water from Missi Falls on into the Rat-Burntwood System via South Bay.

According to a Water Resource Branch Study, the effects of diverting the Lower Churchill River water would be to reduce the volume of the lakes along the river by more than one half and decrease the surface area by one third (Reference 23). This is presuming the minimum flow of the river after regulation to be 500 cfs with no provision to be made on the outlets of the lakes to regulate the water levels. The channel cross sections included within the Branch report were used to determine the impact of the shorelines once the water was diverted.

A further study was undertaken in the winter of 1974 to assess the post diversion ice regime of the lower Churchill from Missi Falls to the estuary. Emphasis was placed on the portion of the river downstream of Little Churchill River (Reference 24).

Throughout the entire waterway, the median regulated water level will be below that of the minimum natural water level, consequently a substantial beach and/or rock area will be exposed.

Under regulated conditions, the vast majority of the lower Churchill River system will not achieve a natural shoreline appearance due to the nature of the exposed materials and the change in water level fluctuation.

With regards to materials, even if the newly exposed shoreline materials are similiar to the natural shoreline materials, the same type of vegetation may not become established in the water-washed zone due to the temporal change and duration of the water level fluctuation. The seasonal distribution of discharges will be advanced by one or two months from the natural condition. This earlier date could influence the type of vegetation that may be established on the newly exposed water-washed area. Moreover, early spring levels may not last long enough to ensure the development of the marsh zone characteristic of Type 14bm, 24, 28 and 31 shorelines.

In general newly exposed mud flats are expected to be colonized by grasses and shrubs. A study conducted in a drawn down marsh in Minnesota revealed that the initial colonization of the exposed mud flats was influenced by seed availability, soil type and moisture and season and duration of drawdown (Reference 25). Aquatic emergent vegetation arising in the first year of drawn down was gradually replaced by greater amounts of upland and shoreline weeds. By the fifth year willow had dominated the sites. A restoration in water levels will result in a change in species composition. This however will likely depend upon the time and duration of flooding, the nature of the residual vegetation and the depth of restored water. A similiar study conducted on the newly exposed deltaic materials of Lake Athabasca has shown that the extensive silt flats emerging from the shrinking lakes and ponds have experienced extremely rapid colonization by germinating seeds that had been present within the silt or were distributed by wind (Reference 26). On the silt flats surrounding Mamaui Lake, the colonization proceeded from an open mud flat with scattered seedlings of sedge and grasses to willows within a four year period. Such colonization processes will likely occur along the exposed mud flats of the lake regions of the lower Churchill River.

The impact on each reach will be discussed separately.

Reach 1 - Partridge Breast Lake: The mean drop in water levels at Partridge Breast Lake will be 9.8 feet. The lake itself has an average depth of approximately 30 feet with the deepest portions being in the channel proper.

The effect of a reduction in levels on Type 13 shoreline will be one of exposing a rock and/or boulder beach in the average of 200 to 300 feet wide below that of the natural water-washed zone. The minimal expected exposure is 100 feet while the maximum is 1000 feet. In comparison, the natural waterwash zone is on the average 150 feet wide. Under a regulated maximum water level fluctuation, the majority of the exposed beach and/or rock zone will be water-washed. The water flushing will not be a consistant phenomenon under mean regulated conditions. The likelihood of a plant cover establishing on the newly exposed rock zone is low due to the type of materials. On most shorelines, the majority of the offshore area consists of bedrock and/or boulders, the exceptions being along depositional sites. Sedge, grasses and possibly willows may become established in the new water-wash zone if alluvium is present. Plant colonization will occur to some extent on the abandoned natural water-washed zone. Sedges will be replaced by grasses and the shrub zone may extent towards the waterline.

Type 13 shorelines downstream of God's Rapids will be effected in a slightly different manner than those of Partridge Breast Lake. The natural water-wash zone averages 50 feet while the regulated water-wash zone averages 600 feet, varying from 500 to 3000 feet. As this portion of the reach contains a fair amount of alluvium, colonization may occur along the exposed relatively flat beaches. The channel depth under mean natural water levels averages about 35 feet along this stretch of the Reach. Under mean regulated conditions reefs will likely be inundated for a period each spring.

Shorelines 14 and 15 of this reach will be effected in a manner similar to that described under Type 13, only the presence of a beach is conducive to the establishment of new plant cover. The exposed material will gradually be colonized by grasses and deciduous shrub and tree growth.

The most noticable colonization process will likely occur on Type 23, 24, 27, and 31 shorelines. The new water-washed zone will also be widest along these shorelines. At present a well marked species gradation exists along the Type 24 shorelines, consisting of sedges, grasses and willows. Under natural conditions this sere would remain as such due to the fluctuation in water levels. However, under regulated conditions mesophytic successional process will be evident. As was found in the Peace-Athabasca Delta project, the sedge meadow will be replaced by grass meadow which will be replaced by deciduous shrubs (Reference 26). Depending upon the substrate, mesophytic successional trend may only be evident on the upper portions of the normal water-wash zone. The fluctuating water levels may keep some of this zone in the early successional sere. Even under extreme low water conditions, these areas will not entirely dry up due to the influx of stream water.

The changes along the Type 23 shorelines are not as great as those described for Type 24 shorelines. Type 23 shorelines are typically found on rivers

flowing into the Churchill River system. The exposed clay banks will likely be quickly colonized once the water level drops. By the end of the Fifty-Year Frame, this shoreline is expected to achieve a natural appearance.

Colonization processes will rapidly take place along the former Type 31 shorelines, possibly allowing the margin of this shoreline to extend out to the new water line. In the regulated situation, however, the anticipated wide fluctuation of water levels may not be conducive to the perpetuation or establishment of a fen shoreline.

The sparcely vegetated water-washed zone of Type 27 and 22 shorelines will remain as they were under natural conditions. Herbacious vegetation and deciduous shrub and tree growth will colonize the exposed beach area.

Type 11 forms the predominant shoreline along the channel extending from Partridge Breast Lake downstream six miles to where the channel widens. The Devil Rapid section is quite shallow, a minimum of 17 feet under normal mean water level conditions with an average range of 25 to 45 feet. Along certain sections the river width will change from a natural distance of 700 feet to 200 feet under regulation. In this situation, the water will be confined to the deepest portion of the channel.

Within the God's Rapids section, the channel is considerably deeper (35 to 60 feet). Due to the nature and slope of the materials, the exposed bedrock beach will not be colonized.

Changes on Type 21 shorelines are primarily ones of colonization on the grass steppe as discussed under "Impacted Process Shoreline for Shorelines," Section 5.4.1. The present belief is that the ice scour will be eliminated over most of the original scour zone along the upper shoreline reaches.

Reach 2 - Northern Indian Lake: The mean drop in water levels at Northern Indian will be 10.3 feet. In general, the exposed zone will be wider than in Reach 1. The horizontal extent of the exposed rock will vary from 50 feet along the steeper shorelines to 7,000 feet within some embayments. The majority of the bedrock control shoreline will contain an exposed area in the order of 100 to 400 feet wide. Under normal conditions, the water-washed zone is from 40 to 120 feet wide. The areas around the larger central island are shallow varying from 15 to 28 feet in depth while the rest of the lake is from 65 to 110 feet deep.

The rapid areas, Northern Indian and Kirkness are shallow (15 to 20 feet). Under regulation, the flow will be confined to the deepest portions of the channel. The river width itself will be reduced by one half or greater along most of the Reach.

The type of colonization processes expected for each shoreline Type are as discussed in Reach 1.

Reach 3 - Fidler Lake: The mean drop in water levels at Fidler will be 8.4 feet. The ramifications of the declining lake levels will be of greater magnitude on Fidler than on all other lakes in the preceeding Reaches. The deepest known depth is 50 feet at the Northern Inlet, while the shallowest known depth is approximately seven feet, in the southeast arm. The average depth in mid-lake is 16 feet. Under mean regulated water

levels a zone will be exposed in the range of 350 to 2000 feet in the east and west shorelines respectively, of the northern portion of the lake. Both shorelines on the central portion of the lake will contain some 2000 feet of newly exposed beach while the southern extensions will no longer be part of the lake basin. These areas will not totally dry up due to inflowing tributaries and local catch basins.

As is the case of the other reaches, a portion of the newly exposed till and/or bedrock beach will be flushed annually. Most of the exposed area will likely consist of a mixture of boulders, gravel and bedrock. Colonization process on such substrate will be similar to those discussed in Reach 1.

The lake basins within the shallower southern extremities contain some alluvial materials. Whether enough is available to facilitate the colonization of grasses and sedges is not known. The absence of riparian vegetation under natural conditions indicates that the offshore areas contain very little alluvium. Most of the exposed area is anticipated to be sparsely colonized with grasses while sedges may develop along the inflowing streams.

Plant colonization will be particularily evident on the Type 24 and 31 shorelines. Fen shorelines will soon be treed while Low Alluvial Shorelines will likely be colonized by grasses and willows. All other shoreline types will be affected in a manner similar to that discussed in Reach 1.

Reach 4 - Fidler Falls: Although little profile data is available, there will likely be little change in river width along the narrower channel portions. The known channel depths in the upper Fidler Falls area are in the range of 25 to 50 feet. Undoubtedly wide beaches will be formed along stretches where the channel widens. As most of the shoreline is bedrock controlled, plant colonization will be minimal. Exposed Type 24 shoreline materials will be colonized by a sparse cover of vegetation in upper areas.

Reach 5 - Billard Lake: In this Reach, the mean drop in water levels will be nine feet in the lake and eight feet in the channel. Under regulation portions of the water-wash zone will not be altered significantly. The steeper shorelines will appear much as they did under natural conditions. The average width of the water-washed zone of 100 feet will range from 200 to 300 feet under regulation.

The maximum known mid-lake depth is 35 feet with a minimum of 13 feet along the eastern arm. Upon regulation, portions of the lake will be divided by reefs while the one island will increase in size.

The hydrophytes present along much of the shoreline, are not expected to reestablish in the offshore areas. Colonization processes along the till and granular lakeshores will be as discussed in the previous Reaches.

Colonization processes within the channel portion of the Reach will vary from that of the lake due to the high occurrence of Type 23, 24 and 28 shorelines. Exposed clay and alluvial materials can be expected to be colonized with willows, sedges and/or grasses, depending on the moisture regime. In this portion of the channel, the newly exposed zone will be from 100 to 1300 feet wide. The irregular channel basin varies in depth from 15 to 50 feet.

Reach 6 - Billard Rapids: As described in the natural state description, Reaches 6 and 4 exibit similar shoreline types, therefore impacts will be similar. The available profiles indicate that the maximum river depth varies from 15 to 20 feet. The water-wash zone will be narrow in most places (40 feet) with a known maximum of 1200 feet.

Reach 7 - Upper Canyon: Within this reach, the mean water level drop will be eight feet up to the Little Churchill River and six feet below the Little Churchill. This reach is characterized by the high occurrence of Type 21 shorelines, the impact will be one of colonization on the grass steppe as discussed under "Impact Process Statements for Shorelines", Section 5.4.1. The anticipated successional processes depend on the elimination of the ice scour phenomenon on the grass steppe.

The channel depth along the entire reach varies from 10 to 45 feet under mean natural conditions while the exposed zone will be from 10 to 800 feet wide. Due to the undulating nature of the channel bottom, the shallower portions will be divided by numerous rocky reefs. Ice scouring, typical of shorelines is expected to reoccur along the lower reaches of the river under post-diversion conditions, but the extent of this phenomenon will be restricted.

Reach 8 - Lower Canyon: Assuming the mean drop in water levels to be five feet downstream from Little Beaver River, the impact on Type 21 shorelines will be similar to that discussed in Section 5.4.1. The Type 12 shorelines peculiar to this reach will not exhibit the exposed till beach characteristic of Type 21 shorelines. The width of the exposed beach measured from the one available profile in this reach indicated that 160 feet of exposed till will be evident on Type 21 shorelines while there will be a minimal exposure on Type 12 shorelines.

Under mean regulated water level conditions a significant amount of channel bed will be exposed, the actual water movement will be confined to the deepest portions of the bedrock channel. Along an irregular channel bottom the water flow may not necessarily be confined to one main channel but spread out over the entire bed. The maximum known water depth under natural mean conditions is 10 feet as indicated by the one available profile.

Reach 9 - Long Island: Under regulated mean water levels, a large portion of the limestone river bed will be exposed and the river itself will be confined to the lowest portions of the channel. Profiles indicate maximum channel depth to be from 9 to 15 feet under mean natural water levels. The newly exposed beach will vary from 10 to 400 feet under mean regulated water levels.

The effect of the declining water levels on the exposed offshore area is as described in the previous reaches.

Reach 10 - The Estuary: The change in mean water levels towards the downstream portions of this reach will lessen because of the influential tidal zone of Hudson Bay. That portion of the channel upstream of Morrier Islands will undergo a four foot change in mean water levels while the water levels while the water surface will only vary by approximately 1.5 feet at the outlet of Goose Creek. The water level will remain relatively constant in the bulbous portion of the channel upstream of the mouth.

In the upper portion of the reach, as in the entire river system, the median

regulated flow is below the natural minimal flow, therefore, exposing a subtantial amount of river bed under median regulated conditions. As an extreme case, south of Long Island, the open water width will change from 7000 to 1000 feet. Under natural median water levels, the deepest known point in the channel is between six to ten feet. In the regulated state with minimum flows, the shallowest portion of the channel at the confluence of Goose Creek and the Churchill River will be two feet. Rather than the flow being restricted to one central portion as is the case in most stretches of the river, the open water is spread out over the channel bed.

Types 13, 24 and 28 shorelines along the upper portion of this reach are characterized by wide offshore alluvium deposits, particularly along the north shore. In this case, shallow shoals 2,000 feet in width will be exposed under median flows. Such sites will likely support marsh vegetation.

Downstream of the Goose Creek outlet, there will be a minute change in water levels and this will diminish as the bay is reached. In this last stretch, the bedrock channel bottom is confined primarily to the central portion of the river as the embayments and channel widenings are sites of deposition. This entire area is characterized by a wide fen shoreline. From available data it would appear that the water line will remain constant under regulated conditions. The decrease in the fresh water supply, resulting in an increased salinity of the estuary water will be of some consequence to the flora and fauna of the area. Under regulation, the stratification of the salt and fresh water, as well as the fresh water plug will disappear in the lower portion of the estuary (Reference 24). The impact on the Fen Shoreline is expected to be contingent upon the species tolerance to the increased salinity.

The effects of reduced flows and related phenomenon on the fresh water supply to the Town of Churchill has been discussed in the "Ice Regime Study" report (Reference 24).

6.5.4 SUMMARY STATEMENT - MISSI FALLS TO HUDSON BAY: The Churchill River, from Missi Falls to Hudson Bay, flows through Precambrian Granites, an area of Paleozoic Limestone, and Precambrian Sandstones for a total distance of 280 miles. The Shield is covered, almost throughout, with a thick mantle of glacial till. The till contains sands, silt, clays and some boulders. The river is embedded in thick marine deposits as it approaches Hudson Bay. Materials are permafrosted along the river resulting in instability of some of the shorelines. Rapids and falls are frequent along the entire route. The water is clear, with slight turbidity at the head of the estuary.

There is a transition in plant communities along with a change in overburden. Uplands at the headwater are characterized by black spruce forest while the vegetation is tundra-like in the Hudson Bay low land.

In its upper portion, the river flows through a series of lakes: Partridge Breast, Northern Indian, Fidler and Billard. Lakeshores in general contain a greater diversity of shorelines than the channel sections. The majority of the lakeshores are characterized by boulder type shorelines. The Churchill River shorelines are distinguished from the lakeshores by the occurrence of vertical rock, active slumping and ice scoured shorelines.

After diversion of the Lower Churchill River water into the Rat-Burntwood River system, the discharge at Missi Falls will be greatly reduced. Average monthly discharge of 36,000 cfs at Missi Falls in the natural state will be reduced to 8,900 cfs in the regulated state. Although the discharges will be decreased, the monthly fluctuation in the regulated state will be increased. The seasonal distribution of discharges will also be changed, peak levels will occur one to two months sooner than normal. The median regulated water level will be below that of the minimum natural level throughout the system. The effect of the lakes along the system will be to decrease the range of discharges but the tributaries will increase the discharge as the river approaches Hudson Bay.

The overall effect of the reduced discharges and subsequent lower water levels will vary depending upon the type of shoreline. However, in most cases the character of the shoreline will be severly altered. The ramifications of the lower levels will be greatest in the lake sections. Here, the mean drop in water level will vary but will average about nine feet. Of all the lakes, Fidler will contain the largest percentage of exposed materials. In this case, extensive mud flats and boulder zones will be exposed over the majority of the lake.

Under mean regulated water levels the majority of the exposed low bedrock shorelines will be anywhere from 100 to 1000 feet wide. Due to the sparce soil cover, these newly exposed zones are expected to be devoid of vegetation. Low lying shorelines containing alluvium and marsh vegetation will undergo a change in vegetative types. The transition in the natural water-washed zone is expected to be one from sedges and grasses to shrubs while the exposed mud flats will likely be colonized by grasses and shrubs.

Under regulation, marsh type shorelines will not re-develop to the extent they were in the natural state. Many of the clay granular shorelines and ice scoured banks will also undergo successional processes. The majority of the newly exposed materials along these shorelines will probably remain barren. Steep banked rivershores will appear much as they did in the natural state. Reduced flows will cause numerous reefs to be exposed within channel sections. Some large islands separated from the mainland will form Peninsulas. Flows will in all cases be restricted to the deepest portion of the channel.

6.6 UPPER NELSON RIVER - LAKE WINNIPEG TO SIPIWESK LAKE

6.6.1 NATURAL STATE CONDITIONS - LAKE WINNIPEG TO SIPIWESK LAKE: The Nelson River stretches approximately 400 miles and has a total descent of 710 feet between its source, Lake Winnipeg, and its mouth, Hudson Bay. It's total drainage area is 414,000 square miles including major portions of Alberta, Saskatchewan, Manitoba, smaller segments of Ontario and several states. About 35,000 square miles drain directly into the Nelson while the remaining area is collected by such rivers as the Winnipeg, Red and Saskatchewan which flow into Lake Winnipeg. The average flow in the Nelson River around its midpoint is 75,000 cfs. Generally the river is turbulent and turbid.

The Upper Nelson channel, irregular in form, winds through the rocks of the Precambrian Shield which are overlain by several feet of lacustrine deposits. This portion of the Channel is characterized by numerous sets of rapids. Downstream of the Shield, through portions of the Lower Nelson, Paleozoic limestones prevail. These are overlain with deep marine sediments, being usually varved clays and silts. In this area the channel straightens out and maintains a constant gradient. Lakes are frequent on the Upper Nelson including Playgreen, Cross, Sipiwesk and Split Lake. Below Split Lake, there are no major lakes on the Nelson system.

The Nelson is the largest river in the Province of Manitoba; its large flow and frequent rapids make it ideally suited to energy production in spite of its distance from major population centres.

The Upper Nelson River: The Upper Nelson River is defined as that section from the outlet of Lake Winnipeg to the head of Sipiwesk Lake (Figure 145). The system includes the associated lakes Kiskittogisu and Kiskitto.

At its headwater, the Nelson River flows through thick Lake Agassiz clay and silt deposits. Throughout the first set of lakes - Playgreen, Kiskittogisu and Kiskitto, bedrock shorelines are irregular and form promontories while erodible organic and granular shorelines form continuous sweeping arcs.

The narrow channels and irregular shorelines typical of the remainder of the Upper Nelson area are a function of the topography. In this case, bedrock controls the shoreline configuration. Outcrops become increasingly predominant in the backshore areas along the downstream portions of the channels.

The West Channel passes out of the extreme northern section of Playgreen Lake at Wiskey Jack Narrows and is joined by flows from Kiskittogisu and Kiskitto Lakes. From here to Cross Lake, the total flow passes through a deep narrow granitic bedrock channel. Rapids are found throughout the channel.

The East Channel flows out of the south basin of Play green Lake through Pipestone Lake into Cross Lake. Narrow channel sections are controlled horizontally by bedrock while widenings are controlled by Lake Agassiz sediments (silts and clays) and may be covered with a thick organic layer. The East Channel is characterized by numerous falls and rapids.

The overall shoreline configuration of Pipestone and Cross Lake reflects the underlying bedrock lithology and structure. Areas of low relief (lake basins) are sites of eroded meta-volcanic and meta-sedimentary rocks while areas

of high relief consist of the more resistant granitic rocks. The numerous islands in the northern portion of Cross Lake are characterized by alluvial shorelines and wide marsh zones.

The channels between Cross and Sipiwesk Lake are horizontally controlled by bedrock and contain several sets of rapids.

The Upper Nelson River has been divided into nine reaches (Figure 145). Shoreline Types for each reach are as shown in Table 47.

Reach 1UN: Playgreen Lake has been divided, at the narrowing of the West Channel, into two reaches. Reach 1UN, the South Basin above Belfour Point, is further sub-divided into two shoreline stretches (Figure 146, 147 and 148).

Stetch 1A: Stretch 1A is defined as the north-east shore of the South Basin, north of Dennison Point, and the whole of the south-west shore from Warren Landing to Belfour Point.

Shorelines are predominantly treed muskeg (Type 26), low willow (Type 28) and fens (Type 31). Backshore areas are typically low and flat; the shoreline is generally concave with only gentle irregularities and a few long triangular points breaking the curves.

Types 26, 27, 31 and 28 form 65 miles of the total of 71 miles of shoreline in Stretch 1A. Types 13 and 14 make up the remainder.

Type 26 shorelines occur over 26 miles of Stretch 1A. Underlain by Agassiz clays and silts, the organic overburden is actively eroding along certain reaches. Wide sand beaches are common along these shorelines, particularly on the north-east shore in the vicinity of Sandy Bar Point where a truncated esker provides abundant sandy gravel. Backshore banks are typically less than five feet high and often are only one or two feet high. Offshore areas are shallow and usually lack a marsh. Occurrences of permafrost are scattered; they are typically marked by homogeneous stands of mature Picea mariana.

Type 27 occurs over 14 miles of shoreline. Long, wide sand beaches are common; the lake is typically shallow up to several hundred feet offshore. Marshes are infrequent in the offshore area. There is usually a steep bank behind the beach, with Populus tremuloides or Picea mariana as dominant species, and with scattered Picea glauca. Less commonly a narrow sand ridge has been formed behind the beach, backed by a low marshy zone. Populus balsamifera is the typical dominant species in open forest on the ridge, with Picea glauca, and with Cornus stolinifera shrubs. The poorly drained area behind area behind is typically overgrown with Myrica gale, Salix spp., Alnus sp., Betula glandulosum, and with scattered Larix laricina and Picea mariana. Ground cover is dominantly Gramineae and Carex spp. Typically either of the above grade back to open coniferous forest of Picea mariana with scattered Ledum groenlandicum on a bed of feather mosses.

Fens border 14 miles of shoreline along Stretch 14. Patterned fens are typical of the Playgreen Lake shorelines. These fens are characterized by the banks of stunted Larix laricina, Picea mariana and Myrica gale with Carex spp., or open water in the flarks. The zones of Picea mariana, resembling treed muskeg, are generally less than fifty feet wide.

Permafrost does not occur under the fens; it is found under the scattered palsas.

The 11 miles of Low Willow Shorelines (Type 28) are located on the sheltered lees of points or at the mouths of sluggish streams. This wide willow zone is most commonly found in association with treed muskeg. The closed shrub zone of Alnus spp. and Salix spp. may be up to one-quarter of a mile wide. The occurrence of Type 22 shorelines south of Sandy Bar Point is due to the truncation of a large esker. A wide sand and gravel beach has formed at the base of a steep forty foot bank of gravel. Neither the beach nor the gravel slope is vegetated. The bank is covered with open stands of Populus tremuloides and Picea glauca. Type 22 makes up some two miles of shoreline.

Four miles of Type 13 shoreline occur only on islands and near Belfour Point; they are described sufficiently in the discussion of Type 13 on Stretch 1B.

Stretch 1B: Stretch 1B includes the north-east shore of the South Basin of Playgreen Lake from the outlet of Lake Winnipeg to Dennison Point.

The overall relief is similar to that of Stretch 1A. However, the shoreline configuration is dissimilar to those in Stretch 1A due to the high degree of irregularity, a direct result of an abundance of low bedrock outcrops. The clay overburden is only of a significant depth in the depressions.

Total shoreline length is 55 miles, with Types 26, 28 and 27 predominating, covering 17, 13 and 11 miles of shoreline respectively. Most promontories are classified as Type 13, (12 miles).

Types 14 and 15 consist of one mile of shoreline each.

Descriptions of Types 26, 27 and 28 are as discussed in Stretch 1A. The only significant differences are the shorter lengths of individual occurrences, chiefly in protected small bays, and in the increased abundance of offshore Scirpus spp. stands. However, these stands are still small and scattered. Also, occasional bedrock outcroppings can be found in the backshore zone.

Type 13 forms irregular promontories, and small island shorelines. Shoreline outcrops are low, wide and smoothly rounded. Outcroppings are occasionally colonized by herbaceous vegetation and Pinus bansiana trees. Backshore areas are characterized by the zone of deciduous shrubs, Alnus spp. and Salix spp. and the open forest of Picea mariana or Populus balsamifera with scattered Picea glauca, Populus tremuloides or Betula papyrifera. The understory typically consists of Alnus spp. with a carpet of feather mosses. Low bedrock shorelines along Stretch 1B usually drop back into treed muskeg several hundred to several thousand feet from the water's edge.

Types 14 and 15 are as described elsewhere in the discussion of the reaches of the Upper Nelson.

Reach 2UN: The West Channel of the Nelson River from Belfour Point to Whiskey Jack Narrows, including the North Basin of Playgreen Lake, has been defined as Reach 2UN (Figure 148 and 149).

The shore of the West Channel from Belfour Point as far north as Lulu Island and much of the shore of the North Basin is of moderately low relief; in the vicinity

of Taylor Island and on the point of land to the north-east, the shore is slightly higher. Shorelines are generally irregular, excepting small concavities eroded into the less resistant sediments lining the small bays.

The 74 miles of Type 13 backshore rarely rises more than 20 feet in 200 feet, commonly as little as 10 feet. Low relief shorelines are commonly associated with Types 26, 27 and 28. The bedrock of Playgreen Lake is weakly gneissic, typically granite, or less commonly diorite, with some scattered mafic inclusions. Shoreline outcrops may be 10 to 30 feet wide; or narrower where they slope more steeply out of the water. Typically outcrops are smoothly rounded by glaciation, with few joints, occasionally with some angular boulders along the water's edge. Overburden above the water-washed zone is of lacustrine silts and clays, with some colluvium, thin on the slopes but deeper on terraces and in depressions. Vegetation is similar to that of Type 13 on Reach 1UN, with some exceptions. The dominant open forest on the slopes consists of Populus tremuloides, Populus balsamifera or Picea mariana. Picea glauca and Pinus banksiana stands are common, Abies balsamea occur occasionally. Typical understory includes Alnus sp., Cornus stolinifera, and Viburnum trilobum, Ribes spp., and Rubus idaeus on shallow slopes. Feather mosses are the dominant ground cover.

Types 26, 27, 28 and 31 are generally as described in the discussion of Reach 1UN. Each type consists of 32, 12, 11 and 15 miles of shoreline respectively. Offshore stands of Scirpus sp., 50-200 feet wide, are much more abundant, more continuous and more dense. Potomegeton spp. are common in fairly shallow water, beyond the Scirpus sp., zones. There are some significant marshes associated with Type 28 in the few small bays.

Types 14 (10 miles) and 15 (7 miles) are similar in relief to Type 13 geology and vegetation is similar to that described for Type 13 in this reach. The beach on Type 14 shorelines is typically overgrown with Salix spp. Offshore Scirpus sp., stands may be associated.

Shores characterized as Type 11 (6 miles) are steep at the shoreline, but the general rise may be little more than 20 to 30 feet in 200 feet. There is typically very little overburden on the slopes, and abundant smoothly rounded outcrops covered in Cladonia rangiferina, crustose and foliose lichens. Lacustrine clay overlies the bedrock where the general slope is broken.

Reaches 3UN and 4UN: Reaches 3UN and 4UN, Kiskittogisu and Kiskitto Lakes are sufficiently similar not to merit separate treatments (Figures 150 and 151). Both are divided into 2 shoreline stretches. The limits of the stretches are somewhat arbitrarily chosen; they are delineated on the accompanying maps.

Stretches 3A and 4A: The upper ends of Kiskittogisu and Kiskitto Lakes are bulbous; the shorelines are long sweeping curves interrupted by gentle protuberances. The basins lie on deep deposits of Agassiz clays and silts, easily eroded by wave action.

Relief along the shores is typically very low; the fens of Kiskitto Lake are essentially horizontal.

Total shoreline lengths of Stretches 3A and 4A are 40 and 20 miles respectively, of which half are treed muskeg (Type 26)

and one-quarter are fens (Type 31). The remainder is of Types 13, 14 and 27.

Type 26 (3 miles) has been described thoroughly in Stretch 1A. Scirpus sp., zones are absent on the upper stretches of Kiskittogisu and Kiskitto Lakes. A wide, swampy beach, almost three miles long, has formed at the head of Kiskittogisu Lake.

On reach 3 patterned fens occur only along the Kiskittogisu River at the head of the lake. The horizontal fens of Kiskitto Lake, Reach 4, may extend as far as four miles back from the lake, interrupted only by scattered permafrosted mineral palsas. These fens consist of 16 miles of shoreline.

Type 13 (7 miles) will be described thoroughly in the discussion of stretches 3B and 4B, where it is very extensive. Types 14 and 27 consist of four and three miles of shoreline respectively.

Stretches 3B and 4B: The north-eastern ends of Kiskittogisu and Kiskitto Lakes lie on Precambrian bedrock, depressions are filled with thick Lake Agassiz sediments. Relief is moderately low; the shoreline is very irregular with low bedrock promontories and small round bays.

Stretches 3B and 4B are 34 and 40 miles long respectively, the remainder of the shoreline consists of Types 14, 15, 26, 27, 28 and 31.

Type 13 shorelines (43 miles) are very low, often less than 4 to 6 feet above water level at distances of 20 - 50 feet back from the lake. The rock is gneissic granite to diorite, glacially scoured to form smoothly rounded hemi-ellipsoids rising at the water's edge. Small cusp-shaped sand beaches are common, but too small to map as separate units. Outcrops and beaches are backed by low clay or silty-clay banks. Scattered herbs grow on the edges of the outcrop, and occasionally Pinus banksiana and Populus balsamifera. The overburden behind the outcrop supports a closed dominant forest of either Populus tremuloides, Picea mariana or occasional stands of Picea glauca. An understory of Alnus sp., Cornus stolinifera, and Viburnum trilobum is very common. Ground cover is typically feather mosses. Very commonly these typical backshore plant communities border on low treed muskeg or fens.

The remaining shoreline types occur frequently on Playgreen Lake and do not differ greatly from their descriptions in discussions of Reaches 1UN and 2UN. Fen shorelines (4 miles) are similar to those of Stretch 4A.

Types 14, 15, 26, 27 and 28 consist of 3, 7, 12, 1 and 4 miles of shoreline respectively.

Reach 5UN: Reach 5UN includes the West Channel of the Nelson River from Whiskey Jack Narrows to Jenpeg at the inlet to Cross Lake (Figure 152). Included is the long neck of Kiskittogisu Lake and the Channel below Kisipachewuk and Metchanais Rapids. Precise limits are indicated on the accompanying map.

The neck of Kiskittogisu Lake is bounded by an irregular shoreline of moderately low relief. It is predominantly bedrock controlled, with clay under treed muskeg along some of the small bays. The water is very sluggish, and wide marshy zones have spread out of the bays and far into the main channel. Below the three

sets of rapids, the shoreline is still irregular, but few of the small, rounded bays, typical of shorelines in treed muskeg, have developed.

Almost all of the shoreline is bedrock controlled; perhaps two-thirds of the channel is lined with outcropping bedrock. Relief is moderate; the channel above Jenpeg shows some of the highest relief on the Upper Nelson River: some slopes rise steeply to beyond 50 feet above the river level. There are few significant marshes along this lower stretch; none comparable to those above the rapids.

Of the 158 miles of shoreline along Reach 5UN, 86 are Type 13, and 8 are Type 11. Most of the 24 miles of Type 15 have very thin overburden cover, with abundant narrow shoreline outcrops. Types 14, 26, 27 and 28 consist of 13, 12, 6 and 9 miles of shoreline respectively.

The boundary between Reaches 3UN and 5UN is particularly arbitrary; change in shoreline characteristics is gradual. Low bedrock shorelines of Type 13 on the neck of Kiskittogisu Lake are very similar to those of Reach 3UN. However, towards Whiskey Jack Narrows, and on the stretch below Kisipachewuk, Metchanais and Ominawin Rapids, low bedrock shorelines are similar to Type 13 on the North Basin of Playgreen Lake. Generally then, shorelines of Type 13 rise 20 feet in 200 feet; the slope increases towards the north-east of the reach. Shoreline outcrops are 5 to 20 feet wide, with smoothly rounded surfaces. For geology and vegetation, refer to the discussions of Type 13 on Reaches 2UN and 1UN.

Shorelines of Type 15 along Reach 5Un, are limited to 2 or three feet of exposed rock and boulders at the water's edge. Backshore outcrops, as on Type 13, are common. Geology and vegetation are as described elsewhere.

Type 11 is limited in Reach 5UN to the channel above Jenpeg. The Shoreline is relatively regular. Bedrock with scant overburden rises steeply as high as 50 feet in the first 100 feet from the water's edge, then falls back to rolling bedrock controlled topography with some treed muskeg. Slopes are forested by Populus tremuloides, Picea mariana, Pinus banksiana or Picea glauca.

Types 14 and 28 may be regarded as differing predominantly in the width of the beach, beaches of Type 14 typically being narrow, less than 30 feet wide. Occurrences are generally short lengths of protected shoreline with outcropping bedrock at either extremity. Bedrock commonly outcrops in the backshore slopes. The beach is overgrown with Salix spp. and Alnus sp.

The remaining shoreline types 26 and 27 do not differ significantly from occurrences on Reach 2UN.

Special note should be made of the very marshy stretch of the neck of Kiskittogisu Lake above Metchanais Rapids, towards Whiskey Jack Narrows. Occurrences of Type 28, low willowed shorelines are especially abundant, and the willowed zones are more extensive than elsewhere along the reaches. Wide marshes extend hundreds to thousands of feet offshore, without regard to shoreline type, depending rather on the sluggishness of the flow and accompanying shallowness of the bottom.

Scirpus sp., is particularly extensive, in waters beyond two feet in depth, with zones of Gramineae and Carex sp., from the beach outwards. Potamogeton spp. are in widespread patches throughout the channel.

Reach 6UN: The East Channel of the Nelson River from the head of McLeod Island at the outlet to Playgreen Lake to the head of Hope Island at the outlet to Little Playgreen Lake is defined as Reach 6UN (Figure 153).

Much of the shores of Little Sepastik Channel and Jack River are of low willow overgrown flats and treed muskeg. Shorelines are relatively regular and of low relief, especially along the upper half of the Jack River and the associated parallel channel. Little Playgreen Lake and the channel to the east of McLeod Island are bounded by bedrock. Shorelines are irregular, relief is moderate.

Of the 104 miles of shoreline, 43 miles are of Type 13, 13 miles of associated Types 14 and 15 and 2 miles of Type 11. Low shorelines of Types 26, 27 and 28 total 46 miles; over half of this length is on the upper ends of Little Sepastik Channel and Jack River. On Little Playgreen Lake they are relatively short and scattered, occuring on bays and protected lengths between promontories.

Marshy shores are not extensive except in the channels above the lake. Vegetation is predominantly mature, although some regeneration forests occur along the lake.

For description of individual types refer to the discussion of Reach 7UN.

Reach 7UN: Reach 7UN is the East Channel of the Nelson River from the head of Hope Island on Little Playgreen Lake to Pipestone Fall just above Pipestone Lake (Figures 154 and 155).

The upper 20 miles of the reach to The High Rock is only moderately irregular; it is essentially two channels separated by many long narrow islands. The only significant break in the water surface is a drop of about five feet at Sea River Fall. Relief is generally low, with occasional bedrock bluffs rising steeply to 20 or more feet above the water. Marsh vegetation along the shores is typical. Most of the stretch has been burned; the better-drained sites are cloaked in regeneration forest; muskeg is essentially unaffected.

At The High Rock the flow divides into widely spaced channels. The main flow is through the westerly one; which is generally similar to the upper stretch, but which again breaks into several channels. The channel to the east is meandering, and divided, running through treed muskeg and marsh of general low relief. Below The High Rock, shores are cloaked in climax forests.

Reach 7UN consists of 173 miles of shoreline. The meandering streams flowing north-east from The High Rock were not included. These shores are largely muskeg and marsh, and would be predominantly of Types 26 and 28.

Almost two-thirds of the length mapped is bedrock controlled; Types 13, 14 and 15 comprise 116 miles of shoreline. The remainder, Types 11, 22, 26, 27 and 28, consist of 1, 2, 27, 18 and 9 miles of shoreline respectively.

Most moderately irregular protuberances along the channel are classified as Type 13 shorelines. Relief is moderate; outcrops are discontinuous and narrow, generally 5 to 10 feet wide, and steep at the water's edge. Bedrock is grey granite, commonly jointed and fractured, forming rounded outcrops with fairly irregular surfaces. The general slope is 10 to 20 feet in 200 feet; the slope breaks, and only local bedrock highs rise higher. Overburden is scattered on the slopes; outcrops common. Lacustrine sediments, clays and silts, or commonly, sands, form the overburden. Very commonly there are scattered Salix spp. offshore. Scattered small herbs grow on soil in depressions and fractures in the outcrop. Above The High Rock, Type 13 shorelines exhibit dense, young regeneration forests. Dominant species are Populus tremuloides, Betula papyrifera, Salix spp. and Alnus sp. with scattered Pinus banksiana and Picea mariana. Rosa sp., Ribes sp., and Epilobium angustifolium are abundant, the feather moss cover is scattered and thin. Mature forests are where Populus tremuloides, Picea mariana and Pinus banksiana dominate the stands, with some Picea glauca. Abies balsamea is very common in mature forest along the channel near Sea River Falls.

Types 14 and 15 are each more extensive than Type 13, and occur in association with Type 13. In Reach 7UN differentiation between Types 13 and 15 depended more on relative abundance of shoreline outcrops than on their width; there being many scattered outcrops along shorelines of Type 13. Generally geology and vegetation on Types 14 and 15 are as described for Type 14. Shores of Type 14 have beaches densely overgrown with Salix sp., Carex spp., (from 0 to 2 feet of water) and offshore zones of Scirpus sp. (from 2 to 4 feet of water). Along the upper part of the channel such wide marsh zones occur, and almost continuous and essentially independent of the shoreline type.

Bedrock shorelines rising higher than 25 feet in the first 200 feet from the water's edge occur over only one mile of shoreline. Shoreline outcrops are continuous and steep; overburden is scant on the slopes.

The occurrence of Type 22 is a sandy gravel ridge below Sea River Falls. The ridge rises steeply out of the water to 30 to 40 feet, then levels off. The shore is lined with continuous zones of Salix sp., Carex spp., and Scirpus sp. The ridge itself is forested in regeneration growth of dominant Pinus banksiana.

Types 26, 27 and 28 are essentially as described in the discussion of Reach 1UN.

Reach 8UN: Reach 8UN includes all of Cross and Pipestone Lakes (Figures 156 and 157).

Both basins lie transverse to the local directions of flow of the Nelson River, in linear depressions associated with belts of pregranitic rocks. Volcanic and meta-volcanic rocks outcrop along most of the shore of Pipestone Lake and on many of the islands on Cross Lake. However, most of Cross Lake's shores are of granite and gneissic granite, with the exception of the shores and islands of the western end, on which outcrops are meta-sedimentary.

The shoreline, particularly of Cross Lake, is very irregular, large islands separating the lake into numerous basins

and interconnecting channels. Narrows called Opatika divide Cross Lake, into a western and an eastern basin. Relief is generally moderately low, with some steep bedrock shorelines. Probably no land in the near vicinity of the lake is higher than 50 feet above the lake level.

Cross Lake is characterized by widespread marshes, long zones of Scirpus sp., off protected shores and across shallow bays. The most extensive marshes on the Upper Nelson River are to be found on the alluvium deposited below Jenpeg and from the west end of Pipestone Lake. They are described below in the discussion of Type 24.

Reach 9UN comprises 870 miles of shoreline, of which 800 are bedrock controlled, classified as Types 13, 15, 14 and 11 in order of decreasing extent. Most of the remainder is of Types 24, and 28, only short stretches of Types 22, 26, 27 and 31 occur. The shoreline classifications are suffixed with an "m" in the majority of occurrences.

Type 13 is typically of low general relief, rising as much as 10 feet in the first 100 feet from shore, but then levelling off. They tend to form promontories or very irregular stretches of shoreline. Outcrops are as wide as 40 feet at the water's edge, and generally smooth surfaced from glacial scouring action. Small sand or cobble beaches are common, usually in small, protected indentations, and with an offshore zone of Scirpus sp. Overburden behind the shoreline outcrop is several feet thick, though there are scattered outcrops.

Backshore forests consist of Populus tremuloides with Picea mariana and Picea glauca, and an understory of Alnus sp. and, less commonly, Sorbus decora. On sand or outcrops Pinus banksiana often dominates. The lower poorly drained areas are characterized by treed muskeg.

Type 14 and 15 backshore are essentially the same as Type 13. Offshore Scirpus sp. zones are typical; they may be associated with marshes as described for Type 14. Beaches of Type 14 are typically overgrown with Salix spp. and Alnus sp.

Type 28 occurs throughout the lake, Type 24 along the channels. Types 24 and 28 are generally similar except that the sediments underlying Type 24 are predominantly alluvial silt deposited around small bedrock cores. Type 28 is typically underlain by lacustrine clay that extends out beneath shallow bays, and under much of the lake. The offshore marshes include zones of Gramineae and Carex spp. in very shallow waters immediately offshore, then Carex spp. growing in abundant stands out to a depth of about 2 feet, and Scirpus sp. in very extensive belts in depths of 2 to 4 feet. Lemna spp. are abundant in the nearshore zone. Potamogeton spp. are also abundant. On wide, low areas behind the shoreline there may be extensive Gramineae or Carex spp., more commonly Salix sp. grows dense to the water's edge. The zone of Salix sp. and Alnus sp. may be 50 to several hundred feet wide; its extent is commonly limited by a low rise and accompanying bedrock outcrops. Vegetation behind the shrub zone is variable, but not dissimilar to the alternatives described for Type 13.

Types 22, 26, 27 and 31 are not extensive on Reach 8UN; descriptions in discussions of upstream reaches will apply here.

Reach 9UN: Reach 9UN includes the Nelson River from Cross Lake to Sipiwesk Lake (Figure 158). Duck Lake and the channel below Little Manitous Rapids is not included.

The river flows out of Cross Lake through a pattern of cross-cutting channels controlled by the structure of the underlying bedrock. Relief along these channels is moderate; nevertheless the shorelines are among the steepest on the Upper Nelson. Five miles above and below Bladder Rapids the river takes a single course, then splits; the larger stream flowing north directly into Sipiwesk Lake, the smaller flowing west and entering Sipiwesk below Duck Lake. Relief is moderate along the channel above Little Manitou Rapids, elsewhere on the lower two-thirds of the reach it is fairly low with only scattered high knolls. Below Bladder Rapids the channel is only moderately irregular, local widenings in the channel and short concave shoreline stretches are related to increased overburden on the bedrock and accompanying decrease in bedrock control of the shoreline. Small bedrock-cored islands are common.

The total lenth of shoreline measured is 96 miles, of which half is Type 15. Types 13, 14 and 11 make up 17, 11 and 15 miles of shoreline respectively. The remaining 5 miles is of Types 24, 26, and 27.

Type 15 shorelines are only moderately irregular; the slope rises less than 20 feet in 200 feet. Relief tends to be less downstream than near Cross Lake. The slope at the water's edge is moderate, and narrow outcrops are abundant, though rarely continuous over long stretches. Backshore outcrops are scattered. The overburden is lacustrine clay and silty-clay under an organic cover usually less than a foot in thickness. Permafrost is typical. An offshore marsh zone as described for Type 14, below, is common, and a dense zone of Salix sp., at the water's edge is typical. The slopes are predominantely forested with Picea mariana. Populus tremuloides and Betula papyrifera are common shoreline trees while Picea glauca is common to backshore areas.

Type 13 is of similar general relief to Type 15, but forms a more irregular shoreline. The shoreline outcrop may be 5 to 30 feet wide. Depth of overburden behind the outcrop is variable, depending on slope. The bedrock may lie essentially flat to several hundred feet behind the shore, then rise gently and outcrop occasionally. In such cases, the overburden, typically clay and silt overlain by coarser overbank deposits, rises gently back to the zone of outcrops. Grain size and thickness of the overlying material is less with increasing distance from the water's edge. Where the initial bedrock slope is steeper, overburden cover is scant below the uplands. Offshore marsh vegetation is uncommon. Very scattered Gramineae, Eleocharis sp., and Potentilla anserina and similar small herbs grow on the shoreline outcrops. Typical forest on coarser sediments is closed deciduous forest of dominant Populus tremuloides, with Picea glauca, Picea mariana and Abies balsamea and an understory of scattered Alnus sp. and other shrubs. Further from the shore, on clay and silty-clay, Picea mariana dominates.

Type 14 occurs mostly on shores protected by adjacent promontories. Generally it is similar to Type 13. Beaches are wide, underlain by clay and silty-clay, and overgrown with Salix spp. to the water's edge. Offshore zones of Scirpus sp., are

typical; they may be 30 to 100 feet broad, and are continuous over long stretches of shoreline of both Type 14 and 15. Carex spp. commonly grows between the shore and the Scirpus sp. zone, but there may be only abundant Potamogeton spp.

Type 11 predominates along the cross-cutting channels leading out of Cross Lake, and on a shore stretch of channel above Little Manitou Rapids. The flows are relatively deep and swift. Dominant forest cover is of Populus tremuloides and Picea mariana.

Slumping is prevalent on the stretches of Type 26 and 27 shorelines.

TABLE 47

UPPER NELSON RIVER

SHORELINE TYPES

CLASSIFICATION	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS
Reach 1 (a)			4				2				26	14	11	14	71
(b)			12	1	1						17	11	13		55
2	6		74	10	7						32		11	15	157
3 (a)			4	4							18	3		11	40
(b)			19	1	6						7	1			34
4 (a)			3								12			5	20
(b)			24	2	1						5		4	4	40
5	8		86	13	24						12	6	9		158
6	2		43	9	4						21	1	24		104
7	1		33	41	42		2				27	18	9		173
8	60		400	90	250		2		23		2	7	35	1	870
9	15		17	11	48				1		2	2			96
TOTALS	92		719	182	383		6		24		181	75	116	40	1818

NOTE: All distances in miles.

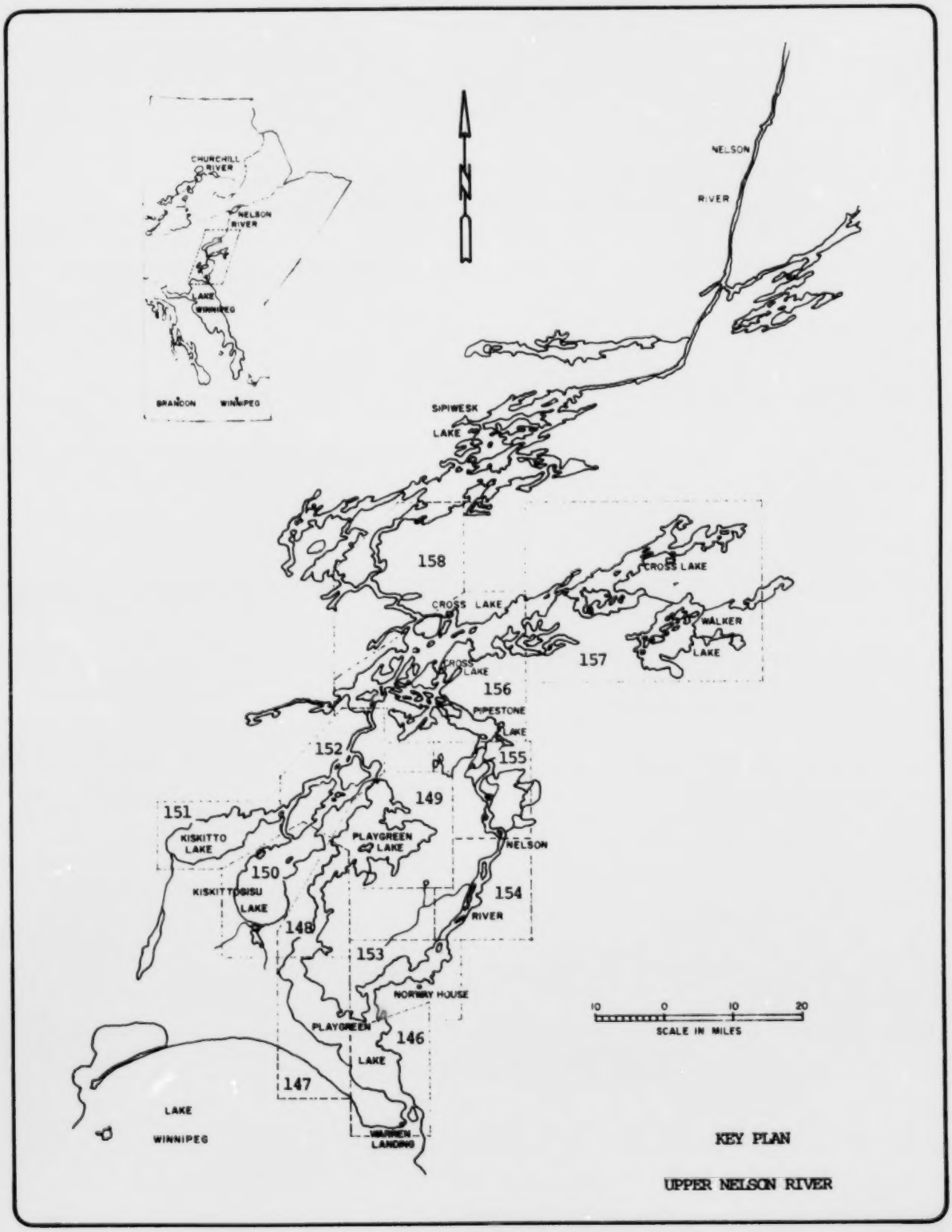

CHURCHILL RIVER
NELSON RIVER
LAKE WINNIPEG
BRANDON
WINNIPEG
N
NELSON
RIVER
SIPIWESK LAKE
158
CROSS LAKE
CROSS LAKE
WALKER LAKE
157
CROSS LAKE
156
PIPESTONE LAKE
152
155
149
151
KISKITTO LAKE
PLAYGREEN LAKE
NELSON
150
KISKITTOSISU LAKE
154
RIVER
148
153
NORWAY HOUSE
PLAYGREEN LAKE
146
147
LAKE WINNIPEG
WARREN LANDING
10 0 10 20
SCALE IN MILES
KEY PLAN
UPPER NELSON RIVER

FIGURE 145

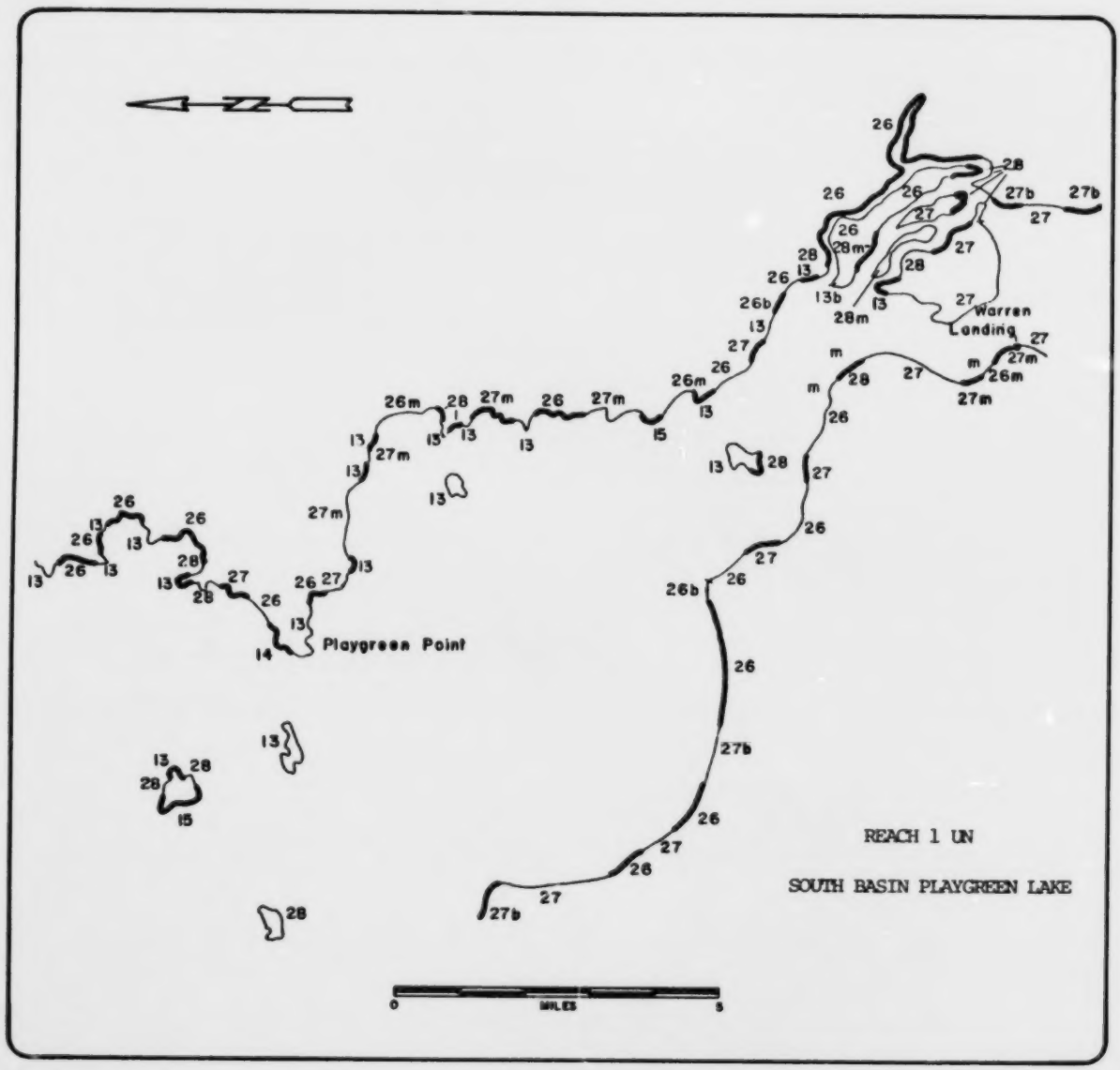

Warren Landing
Playgreen Point
REACH 1 UN
SOUTH BASIN PLAYGREEN LAKE
0
MILES
5

FIGURE 146

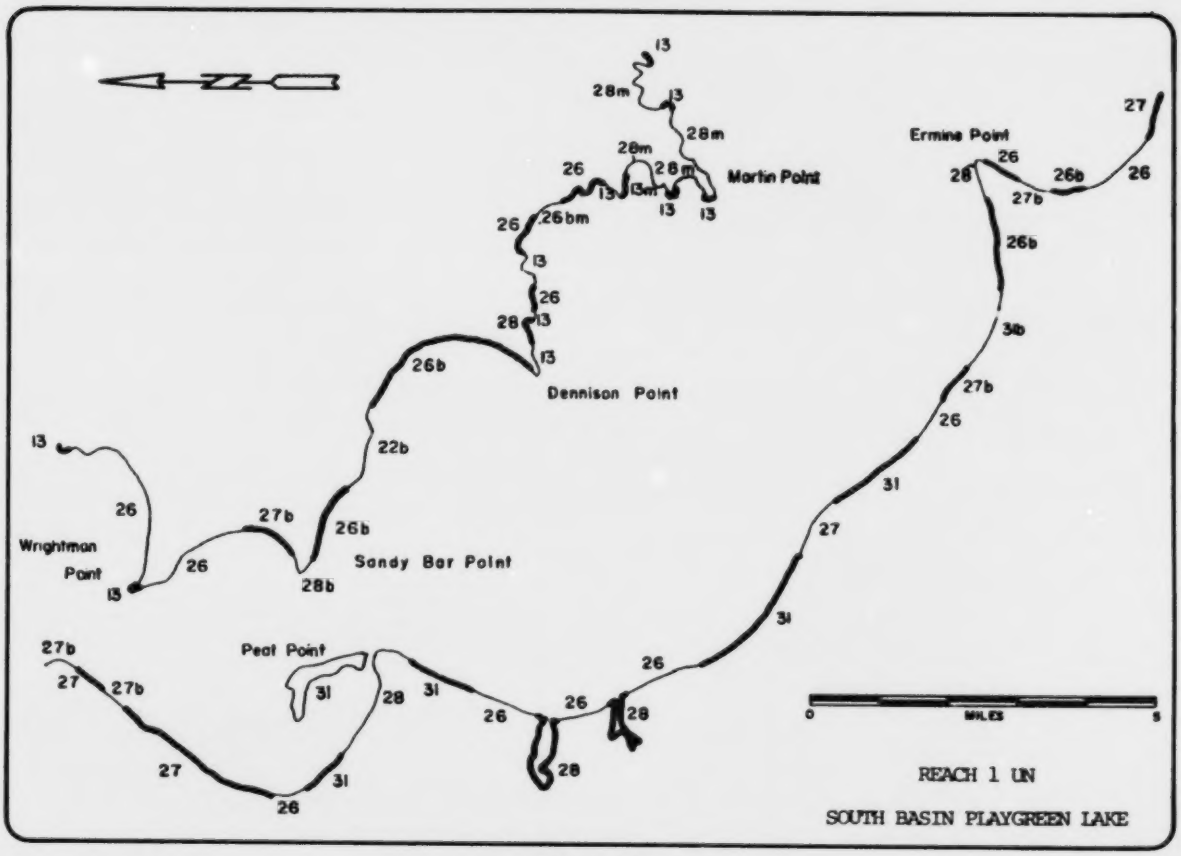


FIGURE 147

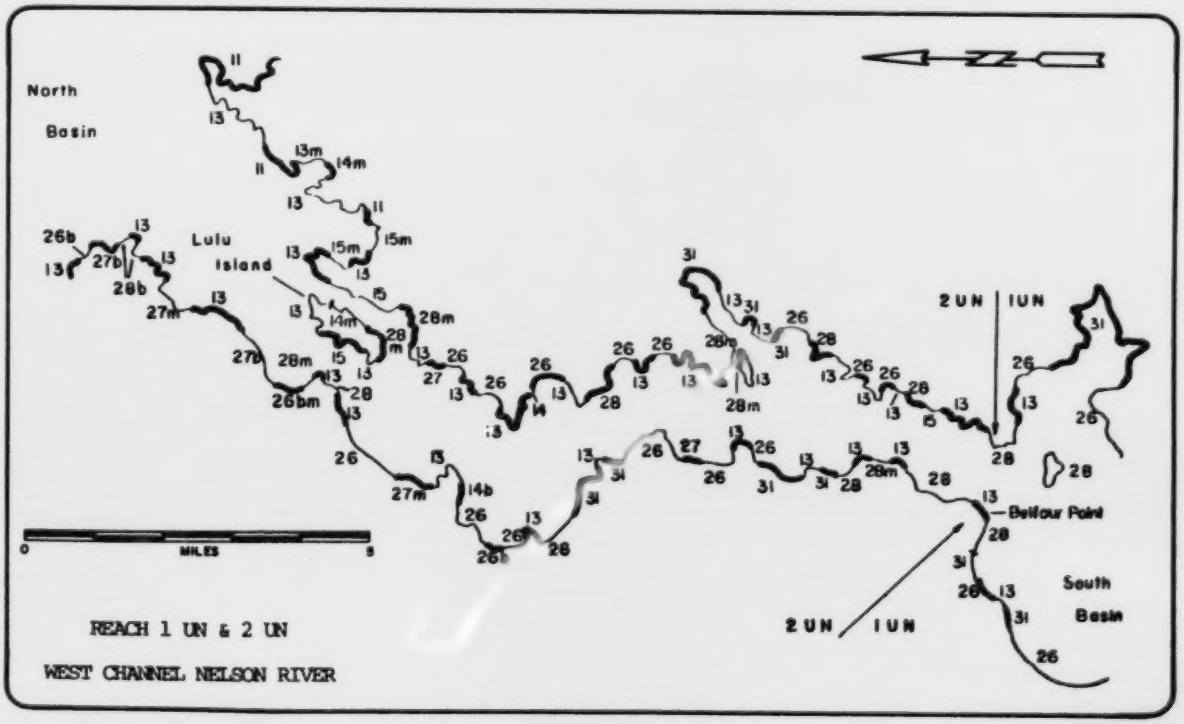
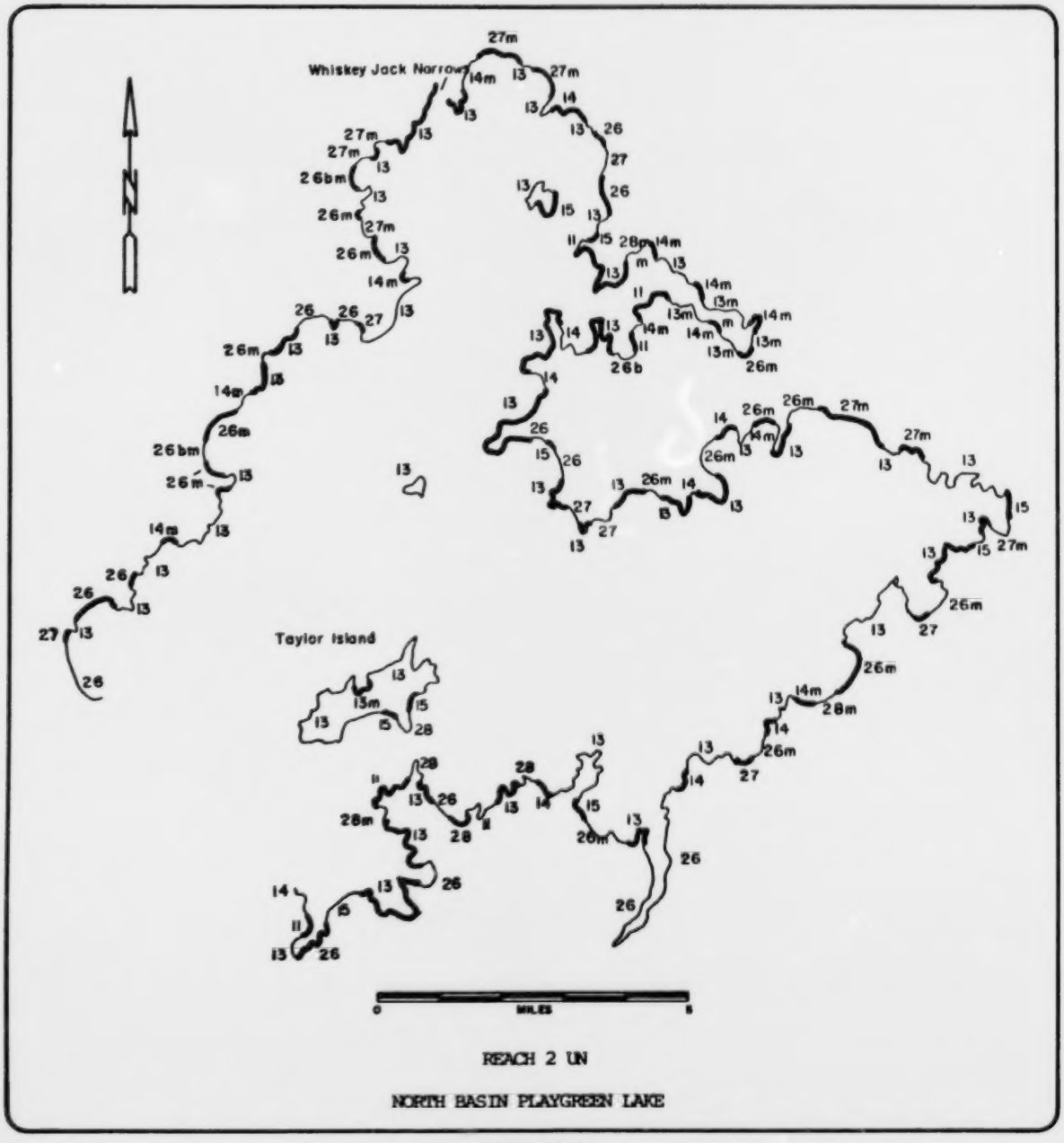


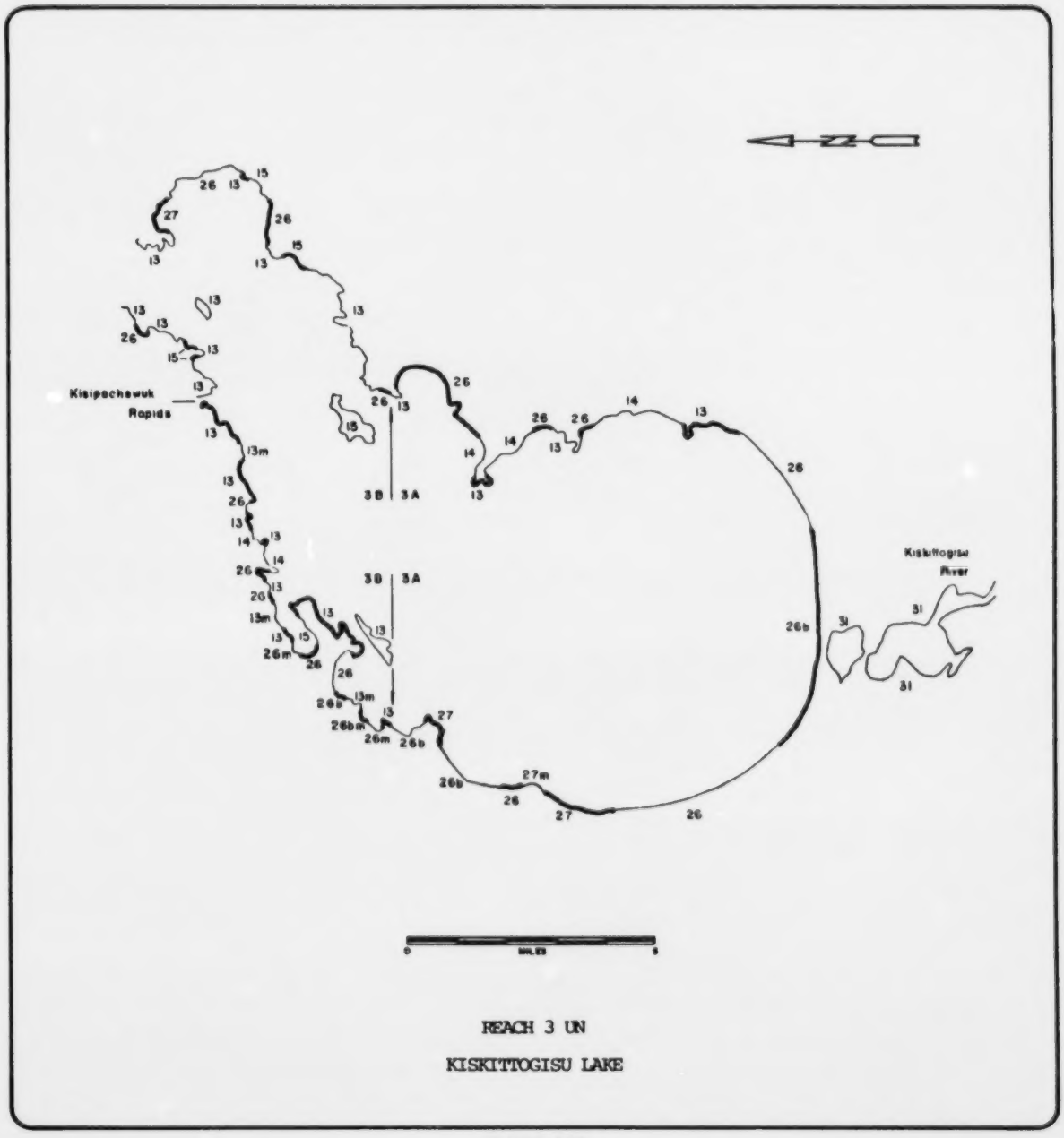
FIGURE 148



REACH 2 UN

NORTH BASIN PLAYGREEN LAKE

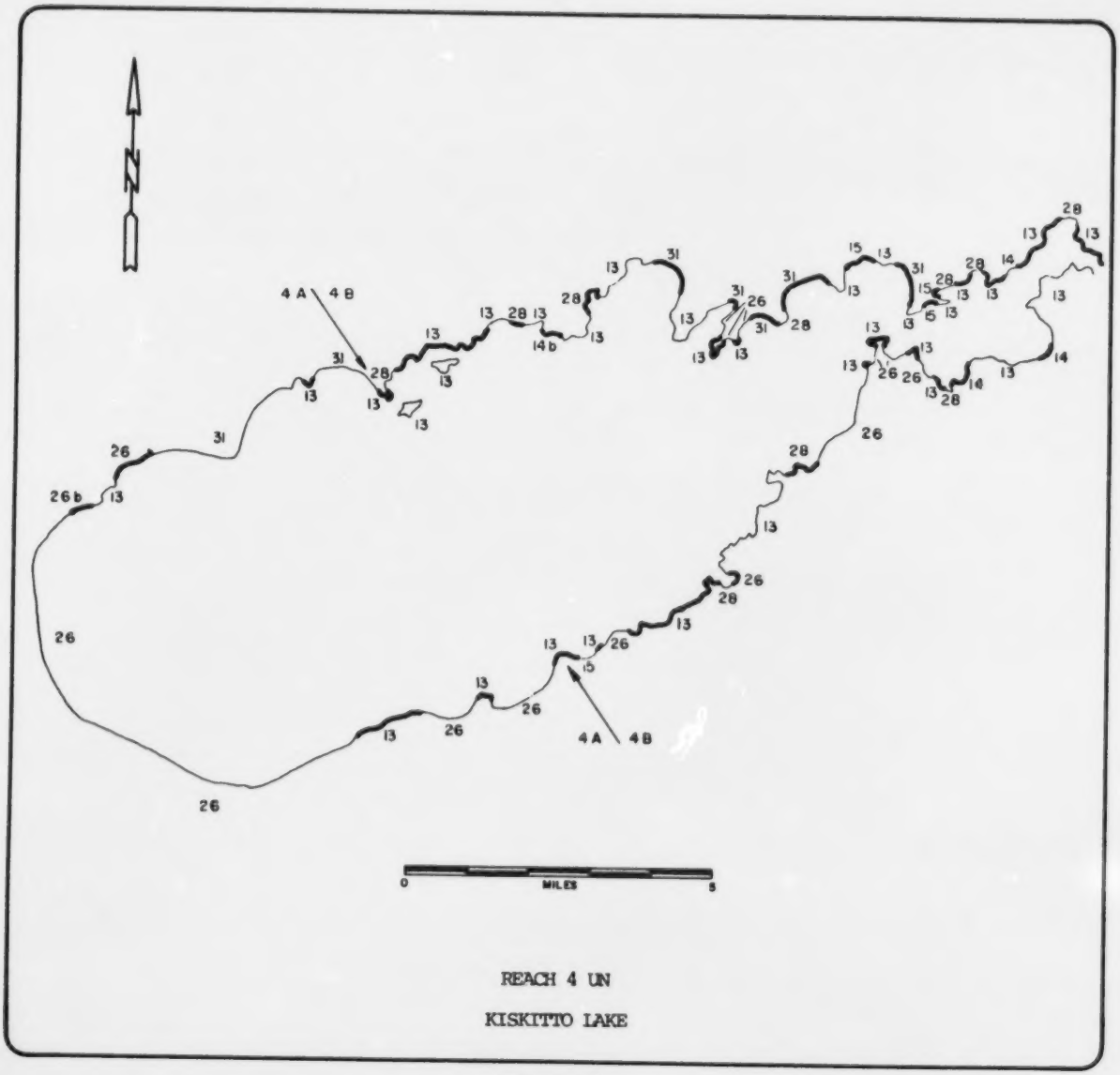
FIGURE 149



REACH 3 UN

KISKITTOGISU LAKE

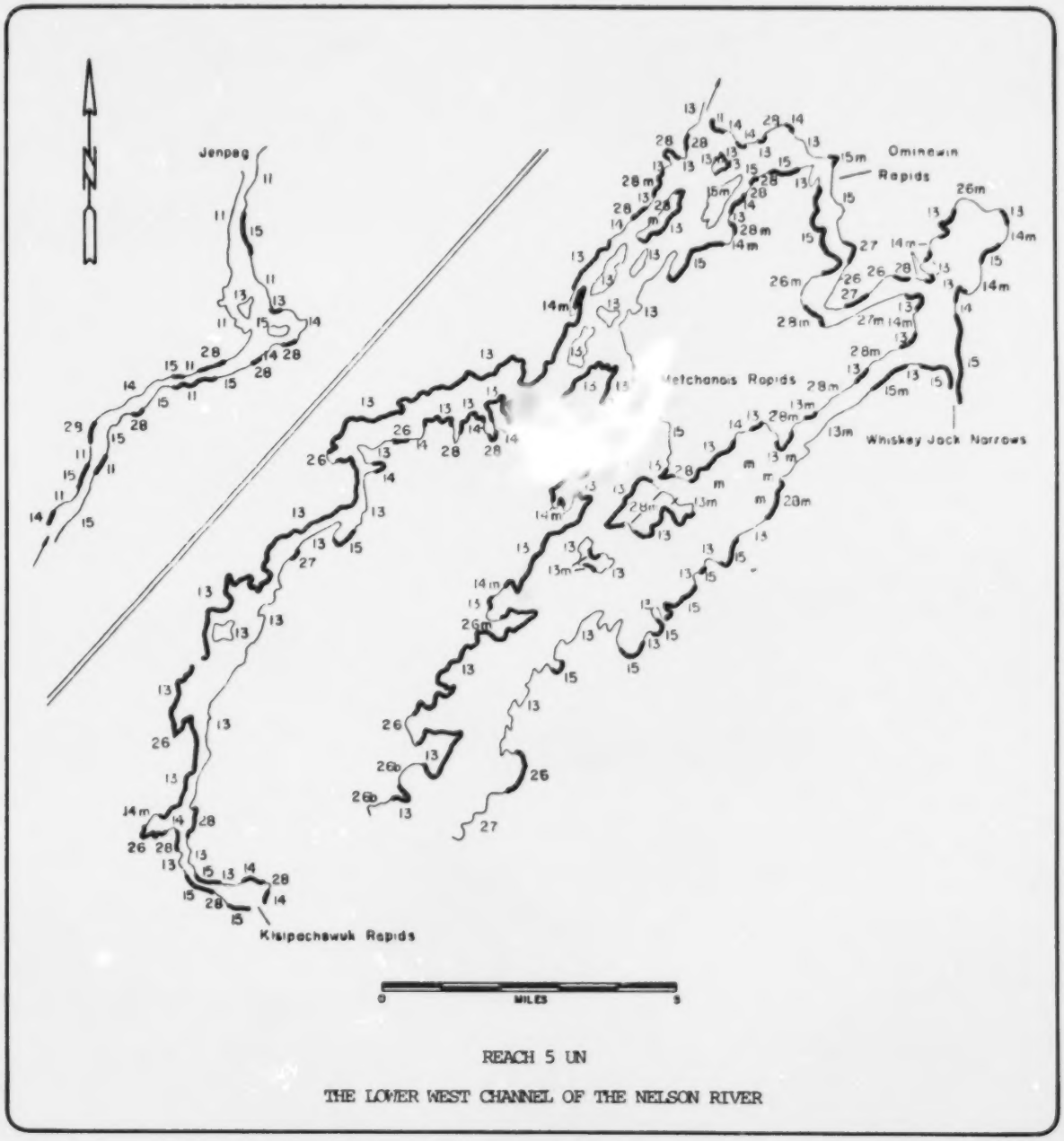
FIGURE 150



REACH 4 UN

KISKITTO LAKE

FIGURE 151



REACH 5 UN

THE LOWER WEST CHANNEL OF THE NELSON RIVER

FIGURE 152

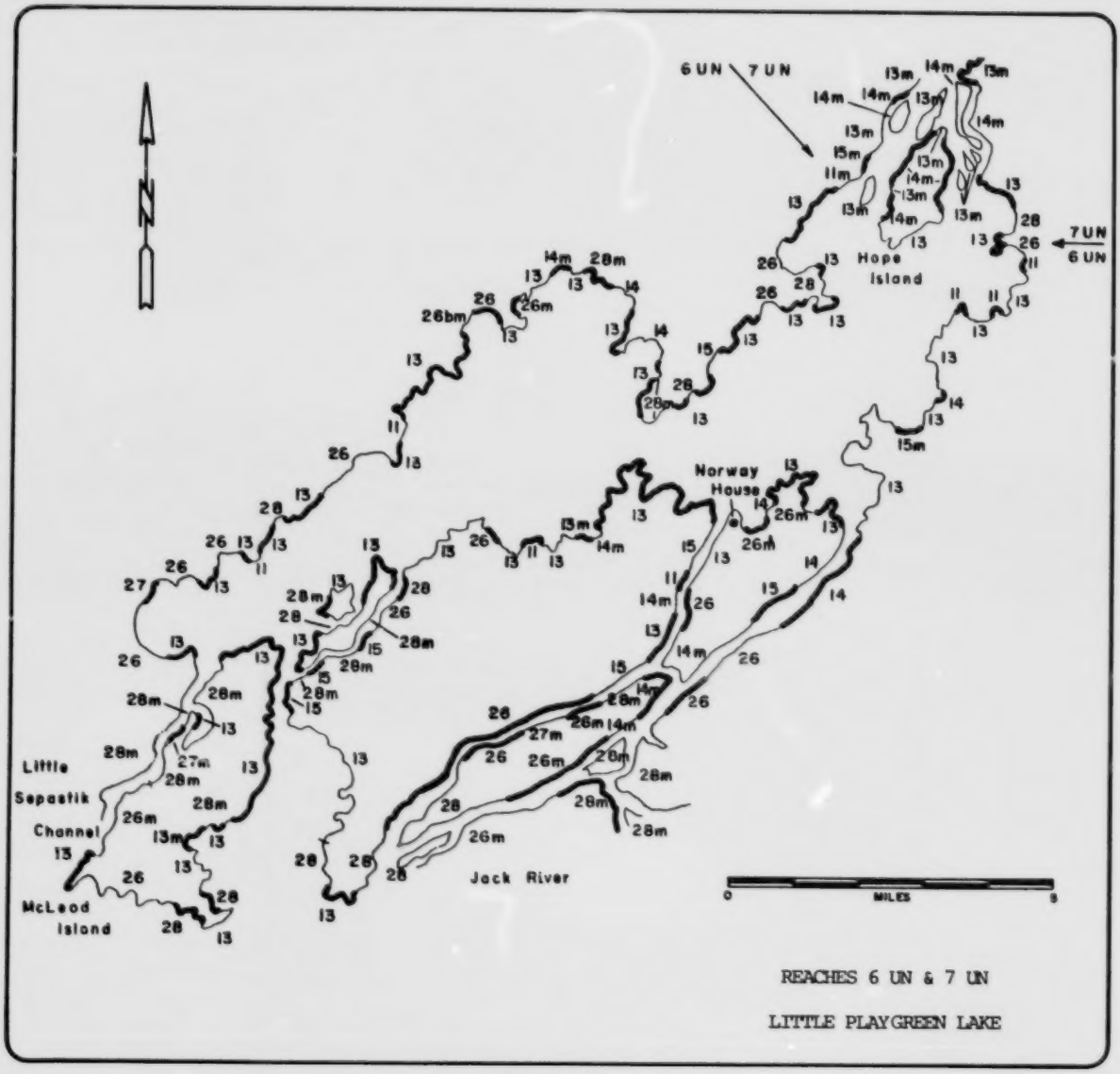

6 UN
7 UN
7 UN
6 UN
Hope
Island
Norway
House
Little
Sepastik
Channel
McLeod
Island
Jack River
0
MILES
REACHES 6 UN & 7 UN
LITTLE PLAYGREEN LAKE

FIGURE 153

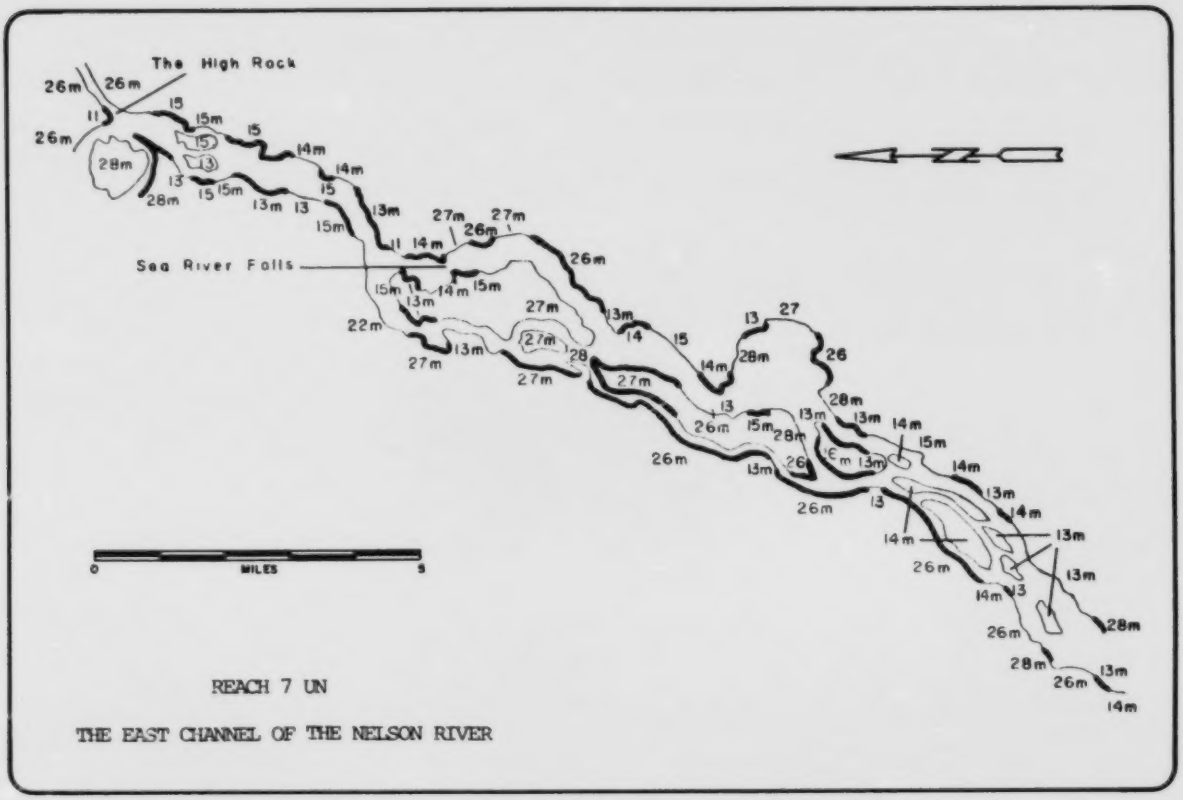


FIGURE 154

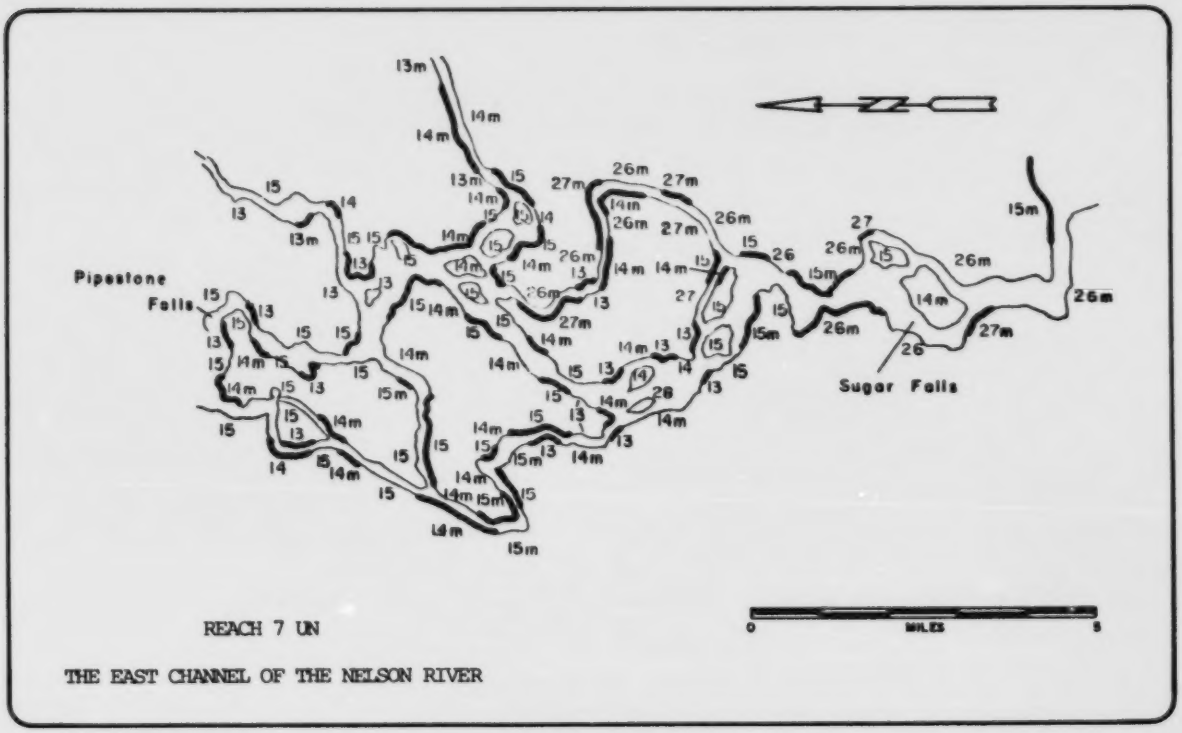
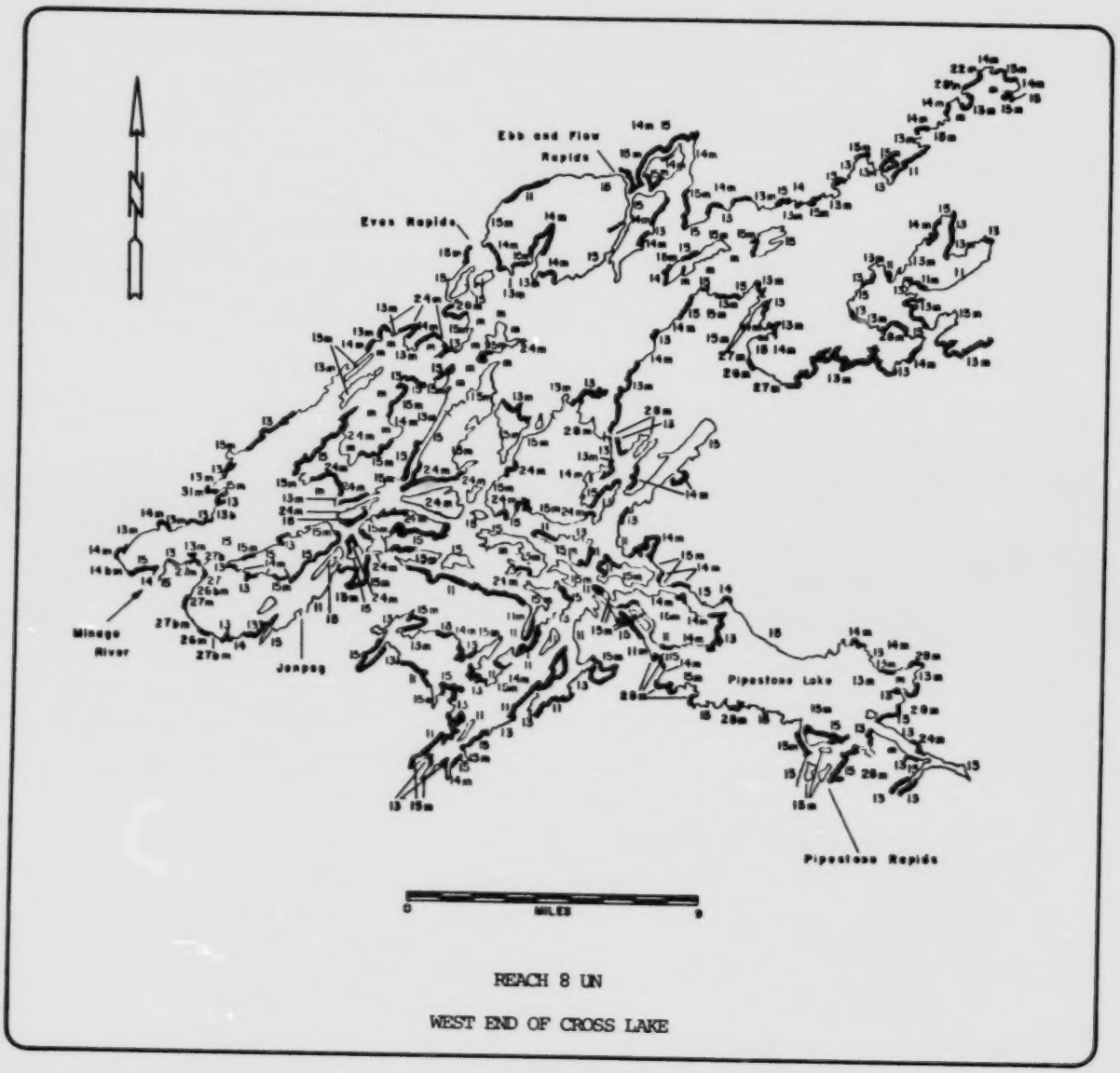


FIGURE 155



REACH 8 UN

WEST END OF CROSS LAKE

FIGURE 156

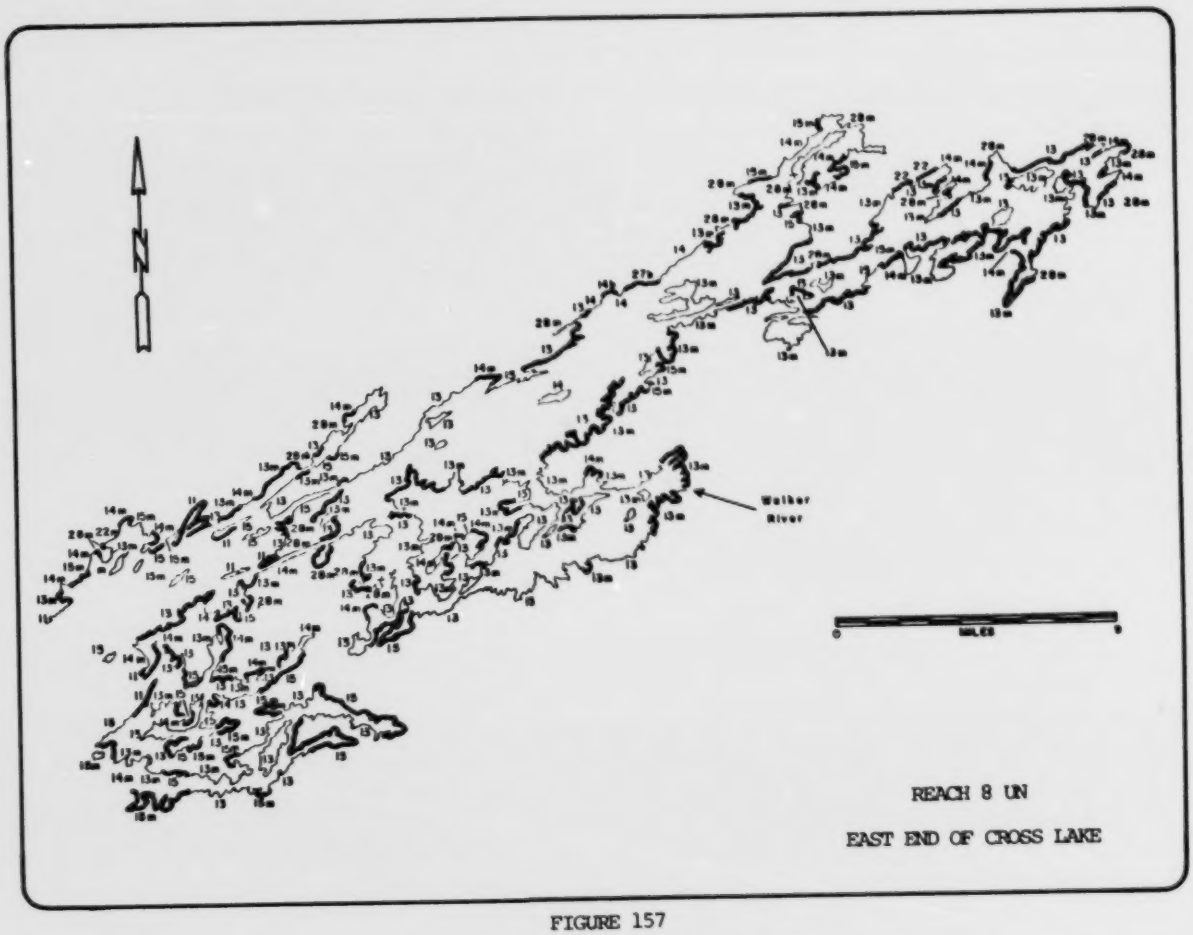


FIGURE 157

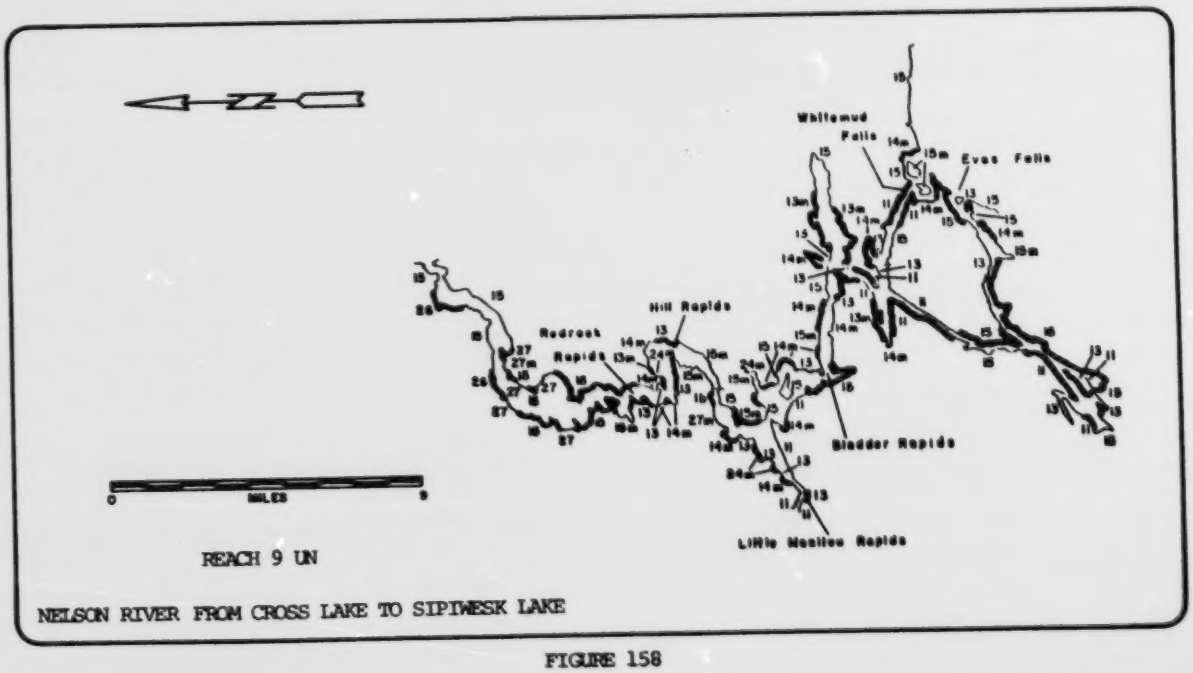


FIGURE 158

6.6.2 WATER LEVELS AND FLOWS - LAKE WINNIPEG TO SIPIWESK LAKE: The Upper Nelson River provides the sole drain for Lake Winnipeg, comprising a complicated network of lakes and channels from Lake Winnipeg to Split Lake. Not far downstream from the outlet of Lake Winnipeg, the Nelson River forms two channels at Lower (Southern) Playgreen Lake. The major portion of the flow is carried by the west channel by way of Upper (Northern) Playgreen Lake, and Kiskittogisu Lake, to Cross Lake. The east channel flows by way of Little Playgreen Lake and through a maze of channels to rejoin the waters of the west channel at Cross Lake. The river soon divides again, however, and flows into Sipiwesk Lake as two channels. From there to Split Lake, a single channel is interrupted only by the Kelsey Generating Station.

Monthly maximum, median and minimum outflows from Lake Winnipeg are shown in Figure 159, for both the natural and regulated state.

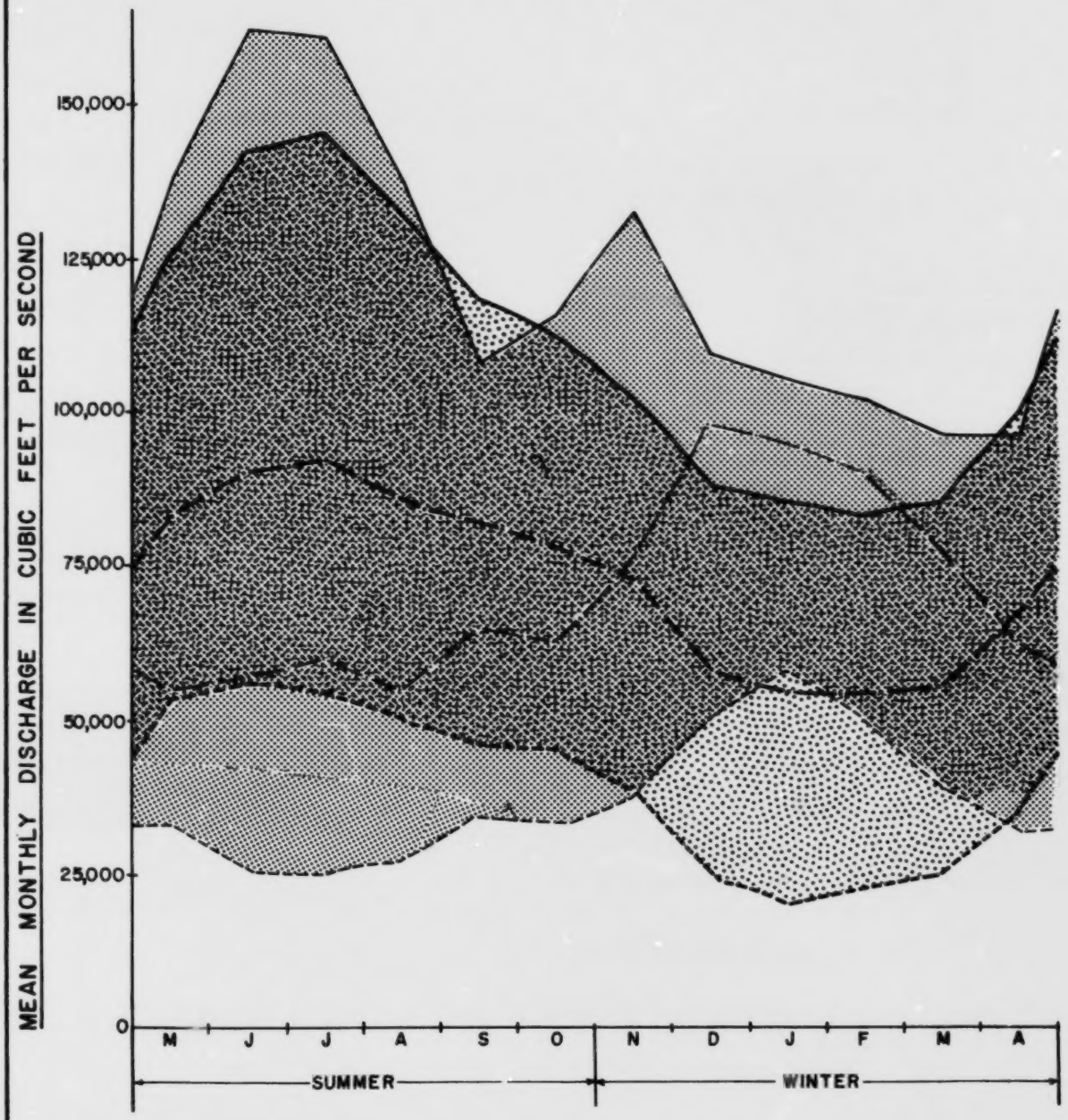
Regulation of Lake Winnipeg outflows will normally result in low discharges during the summer months and high discharges during the winter. Extreme high discharges, however, will occur during mid-summer in periods of very high inflows into Lake Winnipeg and will be as great as 162,000 cubic feet per second. As shown on Figure 159, regulated discharges will generally fall within the natural long term range. Peak discharges will be higher than natural peaks, and the range of discharges will, therefore, be increased.

Short-term fluctuations of discharge will be much more common than in the natural state. Discharges will rise or fall during one month by 40,000 cubic feet per second or more on occasion. These fluctuations will generally occur during the summer months and early winter (November and December). The following Table summarizes the effect of regulation on discharges.

TABLE 48

LAKE WINNIPEG OUTFLOWS

	Natural	Regulated	Change
Minimum	20,000 cfs (Jan)	25,000 cfs (July)	+ 5,000 cfs
Mean	72,500 cfs		
Maximum	145,000 cfs (July)	162,000 cfs (June)	+17,000 cfs
Long-term range	125,000 cfs	137,000 cfs	12,000 cfs
Max. monthly fluctuation			
rise	≤30,000 cfs (May)	40,000+ cfs (summer, early winter)	
drop	≤20,000 cfs (Aug, to Dec)	40,000+ cfs (summer)	



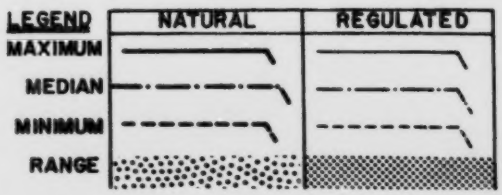


FIG. 159

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY DISCHARGES IN THE NELSON R. AT LAKE WINNIPEG
PREPARED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE APPROVED DATE	SCALE AS SHOWN DATE JAN/74 SHEET 48 OF 58 FILE NO. 61-1-1025

The flows in the west channel of the Nelson River (Figure 160) behave in much the same way as the total Lake Winnipeg outflow. The natural discharges in the summer and low winter flows. Normal regulated flows will be low during the summer and higher during the winter. Extreme high discharges will occur during mid-summer and will be approximately 30 percent greater than natural peaks. The month of July will, therefore, exhibit a great range of flows, from 6,000 to 141,000 cubic feet per second.

Discharge fluctuations will be more common with regulation, occurring frequently during the summer months. Maximum summer variation during one month will be greater than 40,000 cubic feet per second. Monthly increases of greater than 40,000 cfs will also occur during November and/or December every fourth year on the average.

The various discharge parameters are outlined in the following Table.

TABLE 49

WEST CHANNEL OF NELSON RIVER DISCHARGES

	Natural	Regulated	Change
Minimum	20,000 cfs (Jan, Feb)	6,000 cfs (July)	-14,000 cfs
Mean	63,500 cfs	58,600 cfs	- 4,900 cfs
Maximum	110,000 cfs (June, July)	141,000 cfs (July)	+31,000 cfs
Long-term range	90,000 cfs	135,000 cfs	+45,000 cfs
Maximum monthly fluctuation			
rise	30,000 cfs (May)	40,000 cfs (summer early winter)	
drop	20,000 cfs (Dec)	40,000 cfs (summer)	

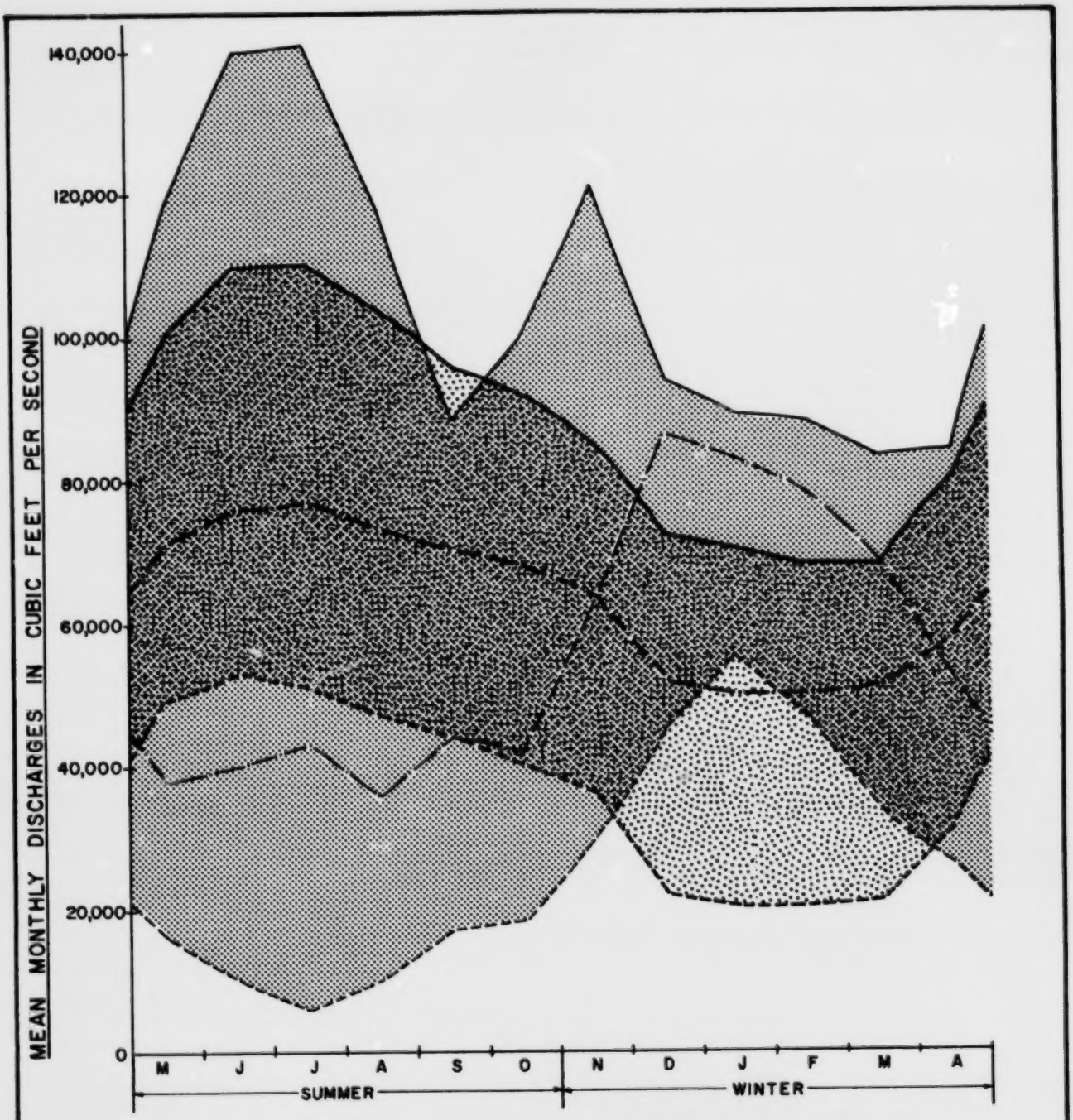


FIG. 160

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
DISCHARGES IN THE WEST CHANNEL OF THE NELSON RIVER

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.	DATE	DATE
	CHECKED F.P.		

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN / 74	49 OF 58	61 - 1 - 1025

Nelson River east channel flows will be altered by the regulated Lake Winnipeg levels. Figure 161 shows the natural and regulated range of discharges. Discharges in general will be reduced, however. Regulation will normally result in high summer discharges, rising to an October peak, and decreasing from there to a late winter low. The long-term range of discharges will be reduced as indicated in Figure 161 ie. regulated discharges, and therefore, water levels will fall within the natural range.

Maximum monthly variations in flow will not be materially increased by regulation, but will occur more frequently. April increases will be as great as 8,000 cfs., which will occur on the average once in four years. Summer fluctuations will be less than the April rises, but will be greater than the natural variation. Reductions larger than 8,000 cfs will occur during November (one year in five), with smaller variations in December.

The various discharge parameters for the east channel are outlined below:

TABLE 50

EAST CHANNEL OF NELSON RIVER DISCHARGES

	Natural	Regulated	Change
Minimum	200 cfs (Jan, Feb)	3,700 cfs (Mar)	+ 3,500 cfs
Mean	9,200 cfs	14,600 cfs	+ 5,400 cfs
Maximum	28,800 cfs (July)	22,600 cfs (Sept)	- 6,200 cfs
Long-term range	28,600 cfs	18,900 cfs	- 9,700 cfs
Maximum monthly fluctuation			
rise	$\leq$ 8,000 cfs (May, June)	8,000 + cfs (May)	
drop	$\leq$ 6,000 cfs (Aug, Sept)	8,000 + cfs (Nov)	

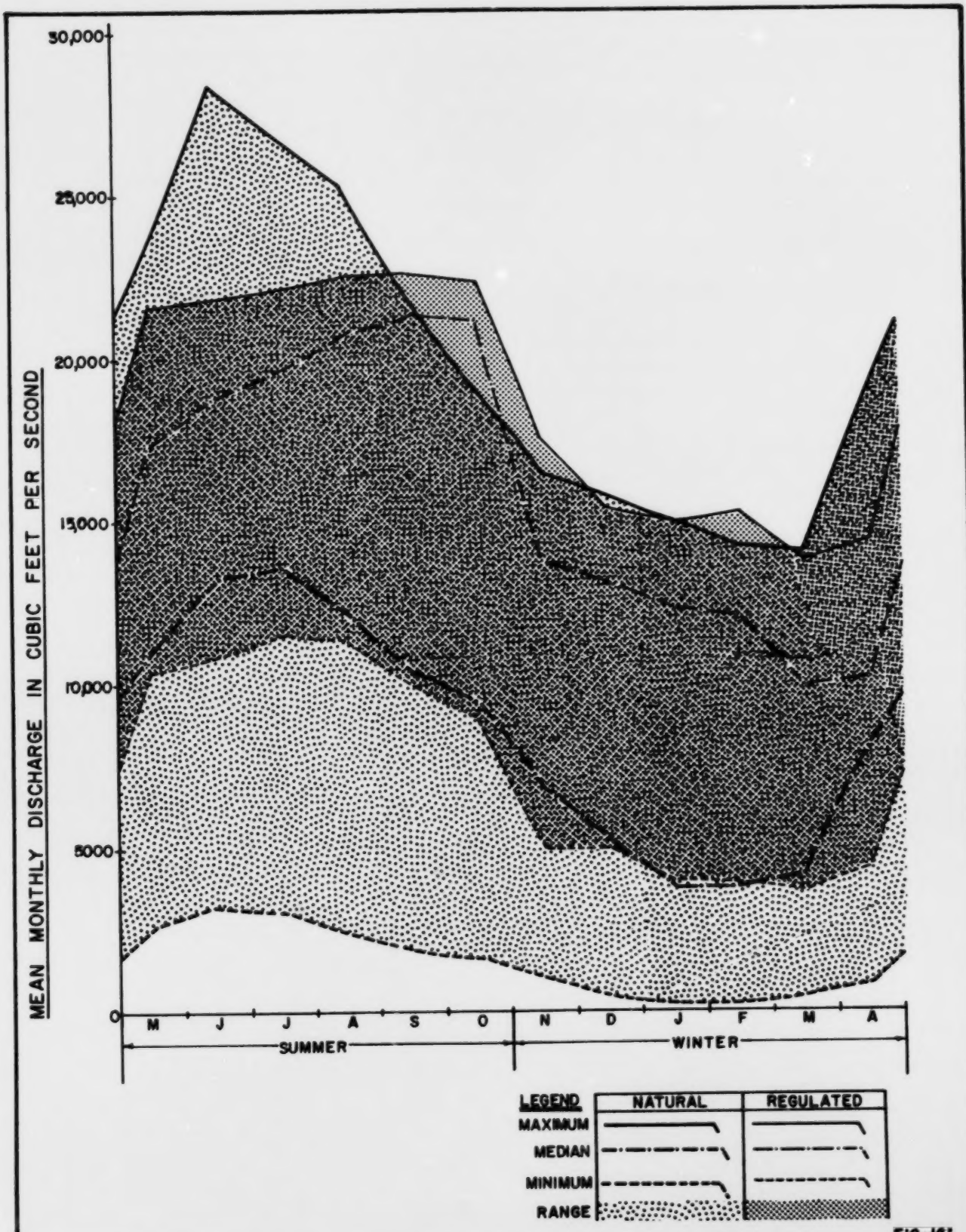


FIG. 161

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
DISCHARGES IN THE EAST CHANNEL OF THE NELSON RIVER

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
L.B.	S.P. CHECKED F.P.	DATE	DATE	AS SHOWN	JAN/74	50 OF 58	61-1-1025

Lower (Southern) Playgreen Lake: Lower (Southern) Playgreen Lake is the portion of Playgreen Lake nearest to Lake Winnipeg. Figure 162 shows natural and regulated water levels for Lower (Southern) Playgreen Lake. With regulation, the water level will be confined to a narrow range within the natural range while peak levels will be reduced. Regulated water levels will normally be lowest in mid-winter, and will rise during the summer to the highest levels in September and October.

The levels of Lower (Southern) Playgreen Lake are also affected by wind setup on Lake Winnipeg. Construction of the Two Mile Channel will permit the levels of the two lakes to equalize more readily than before. Hence, the wind setup on Lower (Southern) Playgreen Lake under regulated conditions may be expected to be greater than under unregulated conditions but still lower than on Lake Winnipeg.

Monthly water level fluctuations will be slightly increased. Water levels will be fairly constant throughout most of the year, with larger fluctuations in May, June, July and November. Rises of one to two feet will occur during May once in 10 years and during June and July possibly once in 50 years. November will experience falling levels in general, with drops as great as two feet occurring once in four years. By comparison, natural fluctuations are generally less than one foot, with the maximum rises of up to two feet on the average occurring during April every second year.

The following table summarizes the various water level parameters:

TABLE 51

LOWER (SOUTHERN) PLAYGREEN LAKE LEVELS

	Natural	Regulated	Change
Minimum	706.7 feet (Dec)	710.9 feet (Jan)	+ 4.2 feet
Mean	711.9 feet	713.4 feet	+ 1.5 feet
Maximum	715.6 feet (June, July)	714.9 feet (Aug, Sept)	- 0.7 feet
Long-term range	8.9 feet	4.0 feet	- 4.9 feet
Maximum monthly fluctuation			
rise	2 feet (Apr, June)	2 feet (May, June, July)	
drop	1 foot (each month)	2 feet (Oct, Nov)	

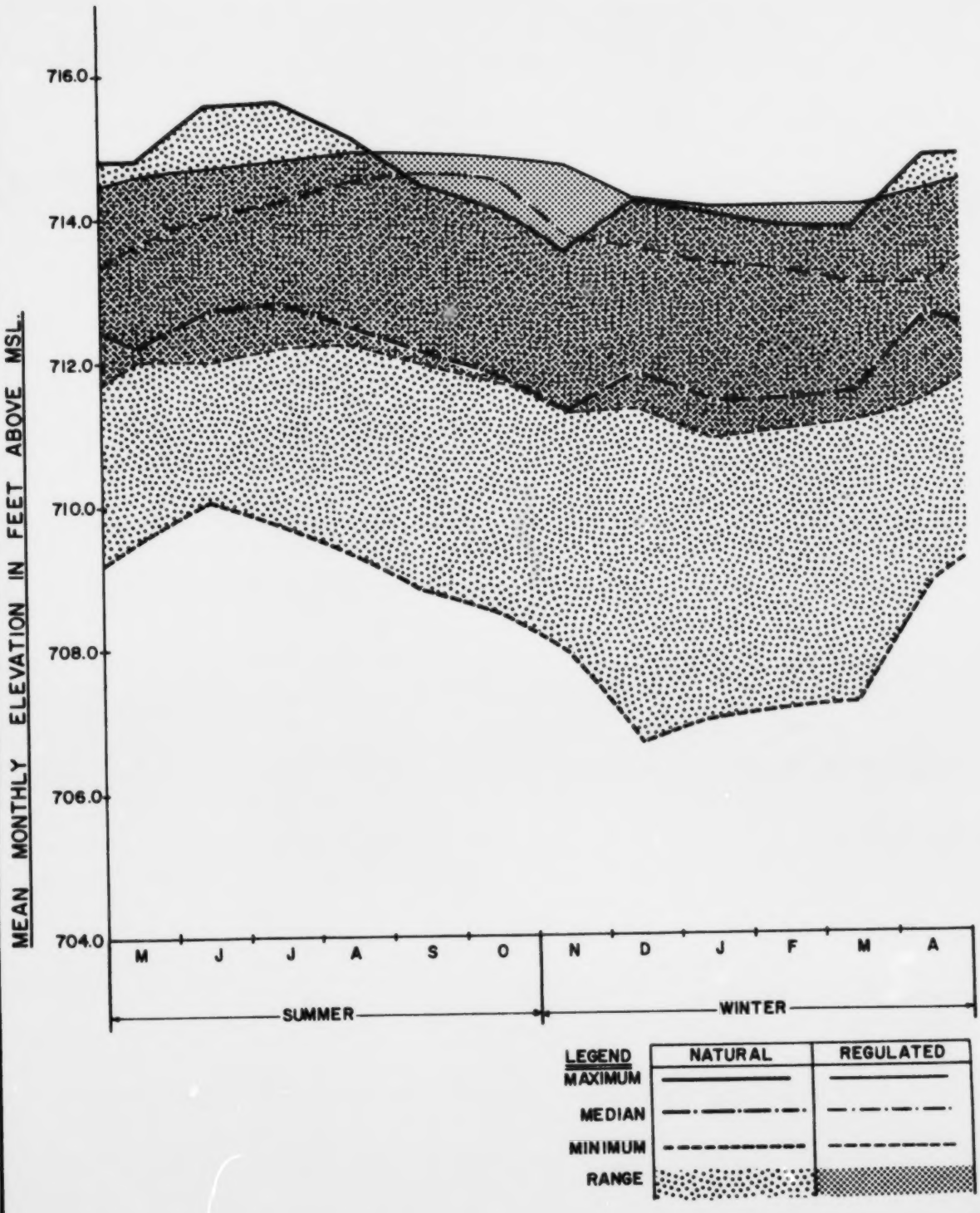


FIG. 162

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS AT SOUTHERN PLAYGREEN LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.	DATE	DATE
	CHECKED F.P.		

SCALE AS SHOWN | DATE JAN/74 | SHEET 51 OF 58 | FILE NO. 61-1-1025

Upper (Northern) Playgreen Lake: Figure 163 shows the natural and regulated levels for Upper (Northern) Playgreen Lake. Water levels will generally be lowest during mid-to-late winter and will rise during the summer to peak in late summer. The range of water levels will be decreased from approximately 11 to 7 feet. Although the peak level will not be significantly increased, high levels will become more common. A level of 714.6, for example, is exceeded on the average only once in 50 years in the natural state, compared to an average of once each year with regulation.

Monthly fluctuations will be increased by regulation. Normal rise or drop during one month is generally less than one foot in the natural state, with a maximum rise of two to five feet occurring in April and May and the maximum drop of two to four feet occurring in December once every 33 years on the average. In the regulated state, the maximum rise in one month will be six feet in May, and the maximum drop will be four feet (in November and January). Fluctuations in one month as large as two feet will be fairly common.

The various parameters are summarized in the following table:

TABLE 52

UPPER (NORTHERN) PLAYGREEN LAKE LEVELS

	Natural	Regulated	Change
Minimum	703.7 feet (Jan)	708.2 feet (Mar)	+ 4.5 feet
Mean	710.5 feet	712.6 feet	+ 2.1 feet
Maximum	714.6 feet (July)	714.9 feet (Aug)	+ 0.3 feet
Long-term range	10.9 feet	6.7 feet	- 4.2 feet
Maximum monthly fluctuation			
rise	< 4 feet (April, May)	$\leq$ 6 feet (May)	
drop	< 4 feet (Dec)	$\leq$ 4 feet (Nov, Jan)	

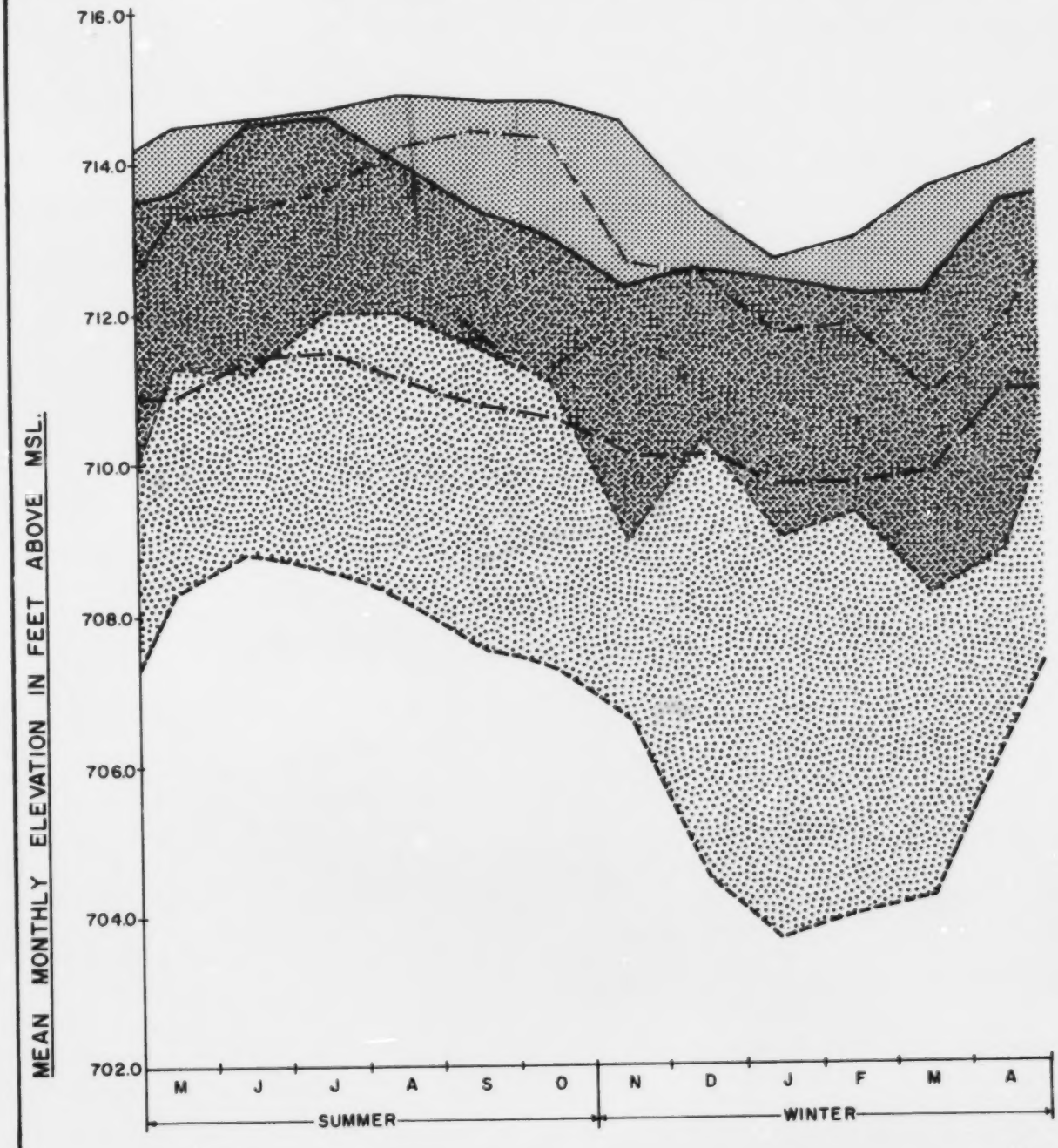


FIG. 163

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
WATER SURFACE ELEVATIONS
AT NORTHERN PLAYGREEN LAKE

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
L.B.	S.P.			AS SHOWN	JAN/74	52 OF 58	61-1-1025
	CHECKED F.P.	DATE	DATE				

Kiskittogisu Lake: Natural and regulated water levels for Kiskittogisu Lake are presented in Figure 164. As for Lower and Upper Playgreen Lake, lowest water levels with regulation will occur during mid to late winter, rising during the summer to late-summer peaks. Natural levels, on the other hand, are highest in early summer, and drop during late summer to a mid-winter low. Water levels will generally be 2 to 4 feet higher with regulation than in the natural state, and will fluctuate over a long-term range of seven feet.

Short-term fluctuations will be increased by regulation. Fluctuations as great as four feet will be common during each of the summer months, with a maximum of six feet or less on occasion in May. Falling water levels will be experienced during November, December and January, with a maximum drop of up to six feet in November occurring possibly once in five years. Drops up to six feet in November may occur once in five years. Drops up to four feet may occur in December and January with a probability of once in five years in December and once in ten years in December.

The various parameters are summarized in the following table:

TABLE 53

KISKITTOGISU LAKE LEVELS

	Natural	Regulated	Change
Minimum	703.6 feet (Jan)	707.8 feet (Mar)	+ 4.2 feet
Mean	709.7 feet	712.3 feet	+ 2.6 feet
Maximum	712.6 feet (June, July)	714.8 feet (Aug, Sept, Oct)	+ 2.6 feet
Long-term range	9.0 feet	7.0 feet	- 2.0 feet
Maximum monthly fluctuation			
rise	$\bar{<}$ 4 feet (April)	$\leq$ 6 feet (May)	
drop	$\bar{<}$ 4 feet (Dec)	$\leq$ 6 feet (Nov)	

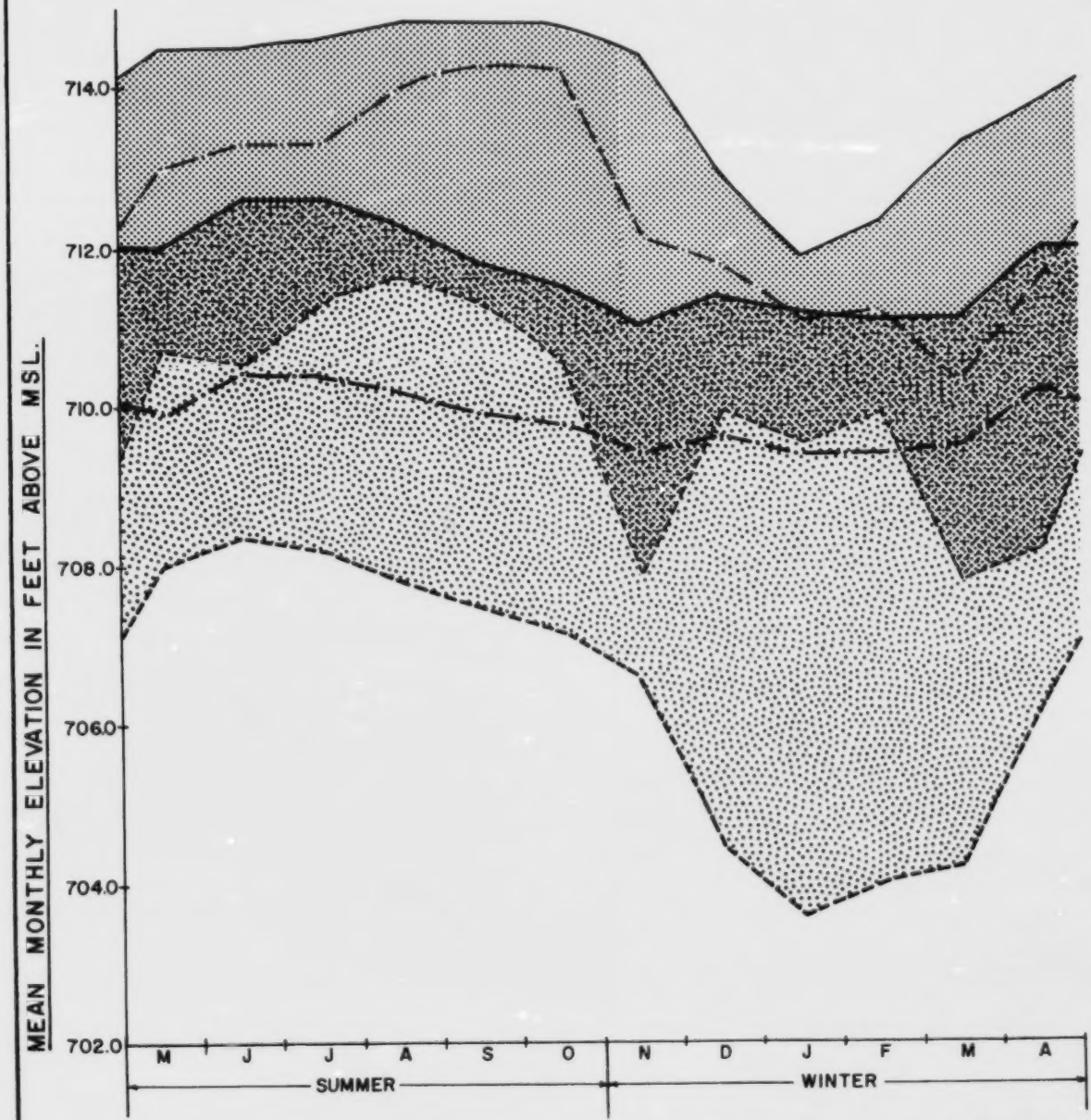


FIG. 164

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY WATER SURFACE ELEVATIONS AT KISKITTOGISU LAKE
PREPARED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE APPROVED DATE	SCALE AS SHOWN DATE JAN/74 SHEET 53 OF 58 FILE NO. 61-1-1025

Kiskitto Lake: Kiskitto Lake will be regulated independently of Lake Winnipeg, and therefore will not display the same water level fluctuation as the rest of the outlet lakes. Figure 165 shows the duration curves of Kiskitto Lake levels for the natural and regulated state. Regulated water levels will be essentially constant, with a maximum range from extreme low to extreme high of three feet. The natural range, by comparison is 15 feet. The highest regulated level will be approximately 4 feet below the natural peak. The median water level will be increased by 3½ feet, ie. levels in general will be higher than natural. Minimum water level will be maintained at elevation 695.

Cross Lake: Cross Lake levels will in general fall within the natural long-term range of levels. Figure 166 depicts the natural and regulated water level ranges. The range of levels (extreme maximum to extreme minimum) will be increased, by about one foot. The regulated long-term mean level will be about one half foot lower than the natural mean. The seasonal distribution of these levels will be changed, however, with normally low levels in summer rising to higher December levels as releases at Jenpeg are increased. Extreme highs, however, will occur in mid-summer during periods of unusually high Lake Winnipeg inflow.

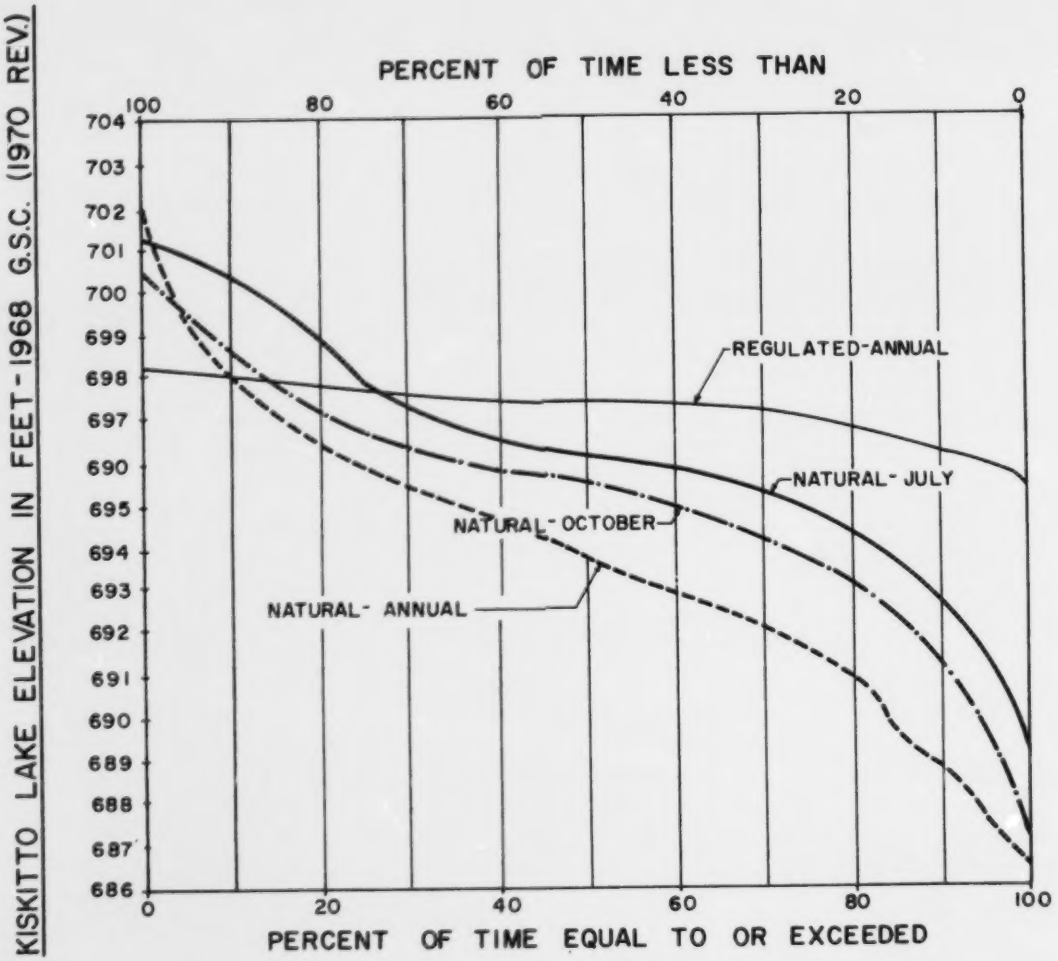
Short-term fluctuations will be increased by regulation. In the natural state, May and June are months of rising water levels (maximum of two and four feet in one month), while November and December display falling levels, with very few exceptions. Maximum natural monthly drop is less than two feet. Monthly variation during the other months is somewhat less. With regulation, rises during one month as great as six feet will be experienced during the months of May, June and July. Dropping levels will also be experienced during these months, however, and will be almost as frequent as rising levels, with rises during one month of between two and four feet occurring once in three or four years for either month. A rise of more than one foot will occur once in two years on the average during either or both months.

The major parameters are summarized in the following table.

TABLE 54

CROSS LAKE LEVELS

	Natural	Regulated	Change
Minimum	674.8 feet (Mar)	674.1 feet (Aug)	- 0.7 feet
Mean	678.5 feet	677.9 feet	- 0.6 feet
Maximum	684.4 feet (July)	684.8 feet (July)	+ 0.4 feet
Long-term range	9.6 feet	10.7 feet	+ 1.1 feet
Maximum short-term fluctuation			
rise	$\leq$ 4 feet (May, June)	$\leq$ 8 feet (July, Aug-rare)	
drop	$\leq$ 2 feet (Nov, Dec)	$\leq$ 6 feet (Aug, Sept, Oct-rare)	



NOTE: -CALCULATED WATER LEVELS IN THE WINTER FOR KISKITTO LAKE ARE APPROXIMATE ONLY.

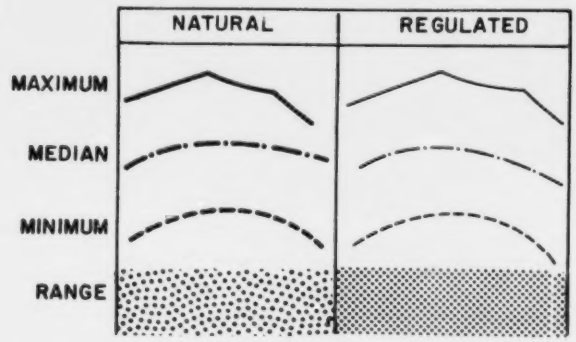
-FULL SUPPLY LEVEL = 695 (CREST ELEVATION OF WEIR = 694).

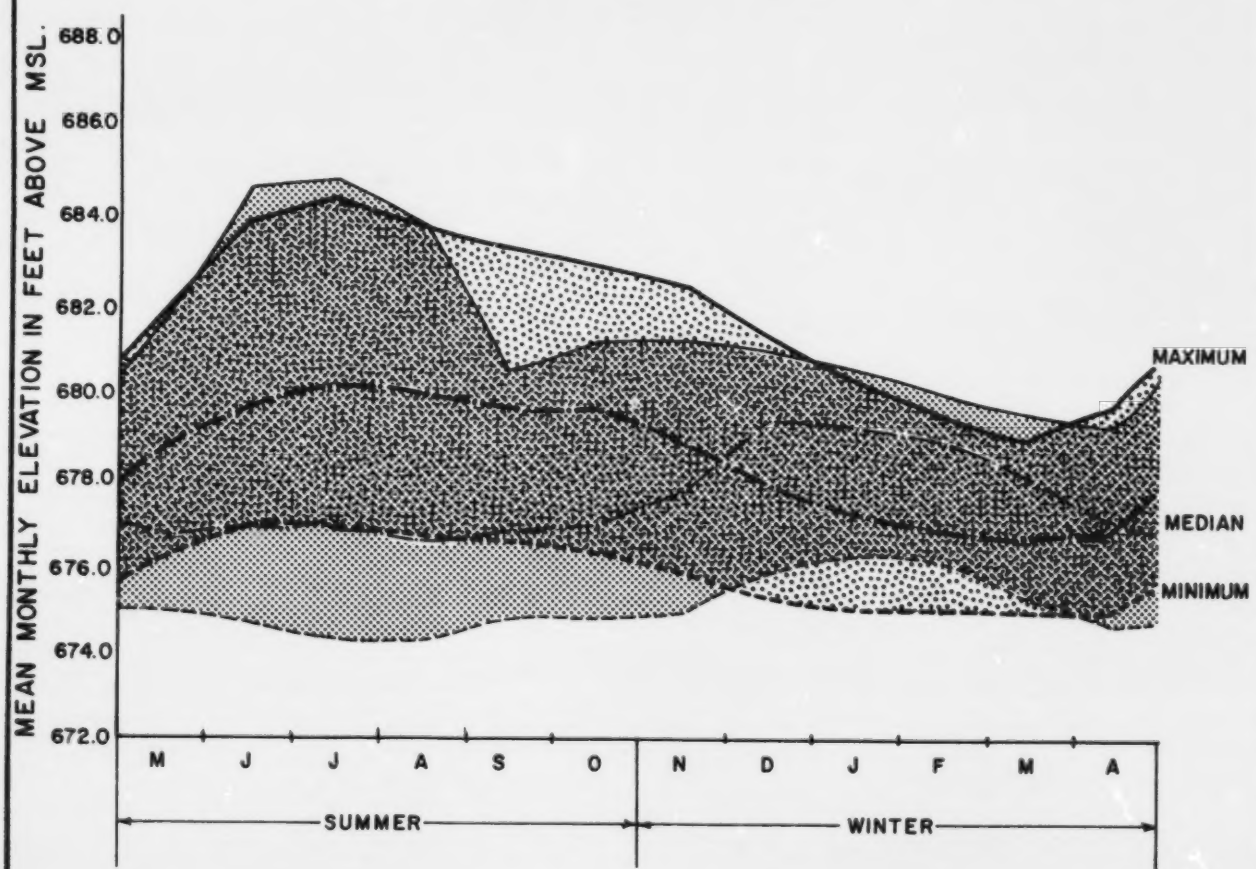
-REGULATED DURATION CURVES FOR JULY AND OCTOBER ARE ALMOST IDENTICAL TO REGULATED - ANNUAL.

FIG. 165

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY WATER SURFACE ELEVATION OF KISKITTO LAKE
PREPARED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE APPROVED DATE	SCALE AS SHOWN DATE JAN/74 SHEET 54 OF 58 FILE NO. 81-1-1025

LEGEND





NOTE: CROSS LAKE COMMUNITY DATUM.

FIG. 166

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY CROSS LAKE COMMUNITY WATER SURFACE ELEVATIONS
DESIGNED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE APPROVED DATE	SCALE AS SHOWN DATE JAN/74 SHEET 55 OF 58 FILE NO. 61-1-1025

6.6.3 IMPACTED STATE CONDITIONS - LAKE WINNIPEG TO SIPIWESK LAKE: The outlet lakes at the north end of Lake Winnipeg that will be affected by the control structure at Jenpeg are Playgreen, Kiskittogisu and Cross Lake. Kiskitto Lake will be isolated from Kiskittogisu Lake and will be controlled independantly.

The impact on these shorelines will be largely as discussed in Impact Process Statements for Shorelines under restricted flooding, Section 5.4.1.

Lower (Southern) Playgreen Lake: The mean natural level of Lower Playgreen Lake is 711.9 feet. With regulation, the water levels will be confined to a narrow range within the natural recorded limits. Monthly levels will generally be higher than the natural levels by 1½ feet, but peak levels will be reduced (Table 51).

Types 26, 27, 28 and 31 form 65 miles of the 71 miles of shoreline in Reach 1UN, Stretch 1A. The raising of the mean water level (1.5 feet) will cause the shrub line to receed to a higher elevation. Types 26, 28 and 27 predominate in Stretch 1B, covering 17, 13 and 11 miles of shoreline respectively. Backshore banks are typically less than 5 feet high along Stretch 1A and also along Stretch 1B with the exception that the latter is more irregular in land form. With regulated water level conditions, maximum monthly fluctuations will rise less than two feet during any one month of May, June and July and drop less than two feet during October and November. Under natural conditions maximum monthly fluctuations will rise less than two feet during any one month of May, June and July and drop less than two feet during October and November. Under natural conditions maximum monthly fluctuations rise less than two feet in April and June and drop less than one foot in any one month (Table 51).

Upper (Northern) Playgreen Lake: The mean natural level of Upper Playgreen Lake is 710.5 feet. With regulation, the long term range of water levels will generally be decreased by about four feet (Table 52), but peak or maximum levels will be increased by 0.3 feet. Monthly increased level fluctuations under natural conditions are as great as four feet during April and May and up to six feet with regulation during May.

Approximately one-half of the lake shoreline is Type 13. Types 26, 27, 28 and 14 form most of the remaining portion with minor stretches of 11 and 15. On Type 13 and 14 shorelines, erosion of the clay overburden will occur to form the new shoreline at the increased water level (0.3 feet rise). Low relief shorelines: Type 26, 27 and 28 will only be slightly affected by the 0.3 foot increase in water levels. Backshore flooding and accelleraated slumping (particularily along Type 26) will occur. The new shorelines will quickly achieve equilibrium. The effects of a water level rise will be negligible on Type 11 shorelines.

Under regulation, the marsh zones of Upper and Lower Playgreen Lake will be affected by the change in water levels. Although the maximum water level increase or decrease is slight, a reduction in the range of water levels and a temporal change in fluctuation periods will influence the vegetation. In both lakes, water levels that naturally peak in mid-summer will continue rising until early fall in the regulated state. This will undoubtedly influence certain emergent marsh species that require a reduction

in water levels throughout late summer. A reduction in ranges will also reduce the width of the water-washed zone.

The change in water levels, as mentioned, will not only reduce the total width of the marsh zone, but also be instrumental in changing the species composition of the marsh zone.

Kiskittogisu Lake: The mean natural level of Kiskittogisu Lake is 709.7 feet. With regulation, the mean level will be raised 2.6 feet to 712.3 feet and fluctuations will generally be two to four feet higher than natural levels with a maximum of six feet or less rise in May (Table 53). Decreased water levels of less than four feet will occur during November, December and January. The southern shoreline of Lake Kiskittogisu is a long sweeping curve. Twenty-five miles of shoreline are Type 26, while 11 miles are Type 31. Water level increments in the order of three feet will have an impact on these types because of their low relief. At the south side of Kisskittogisu Lake, about 1½ square miles will be flooded (Reference 27). Shrub and tree mortality will occur in the inundated zone. Portions of the fen will rise while some areas may become much more productive due to the breakdown of organic materials, thereby reverting the area to the earlier plant successional stages. Numerous ducks, geese, and wading birds were observed feeding on invertebrates in a flooded fen bay in Sipiwesk Lake (Photograph 120). Wave action will be instrumental in forming new shorelines by piling up some of the floating organic debris within a relatively short period of time (ten years).

Treed Muskeg, Type 26, occurs in the bays, and in particular near the south end of Reach 3B. Photograph 121, of this location shows the slumping shoreline. The water level was 711.9 feet (personal communication L. Leung, Water Resources) on September 4, 1974 when the photograph was taken. This level is 0.4 feet below the regulated mean of 712.3 feet. Photograph 122, taken on the same date shows a stunted black spruce backshore bog. Most trees have reached a height of less than five feet. The roots of these trees will become water logged resulting in die back. These shorelines will continue to erode until a scarp is formed and eroded materials have accumulated to form an offshore bench.

Lacustrine clays are thinner in the northern part (Stretch B) than in the southern part (Stretch A) of Kisskitogisu Lake (Figure 167). This is evidenced by rock exposures backed by rock exposures backed by low clay banks with trembling aspen, Populus tremuloides (Photograph 123) or black spruce, Picea mariana. The shorelines are predominantly bedrock controlled (77%) interspersed with short sections of treed muskegs (21%) in protected bays. There is a large glacio-fluvial area of sand deposits off the east shore, east, northeast of Kiskipachewuk Rapids (Figure 167). The 715 and 725 contour lines are not available for this area and since this is low level topography, flooding of undetermined extent will occur. At this location, there are four miles of Type 27, Low Shoreline in Coarse Sediments. Re-establishment of the beach at a higher level will occur within a ten year period. Present backshore vegetation may re-establish at a higher level as conditions stabilize. From this point,

(Type 27, Figure 167) proceeded north, north-east along the east shoreline to Whiskeg Jack Narrows the shoreline is approximately equal parts Types 13 and 15. In both cases, the clay overburden will erode to the maximum water line. Due to the depth of overburden and vegetation, the impact on a Type 15 shoreline will be greater than on a Type 13 shoreline. There will be complete loss of some low-lying islands through flooding and erosion.

On the north-west shore of the northern arm of Kiskittogisu Lake (Kisipachewuk Rapids to Whiskey Jack Narrows), the shoreline is extremely irregular (Figure 167). Type 13, low bedrock shoreline, predominates. The remainder of the shorelines are Type 14, 15, 26, 27, 28 and 31. Relief is moderately low and the small bays between the bedrock promonotories contain varying depths of Agassiz sediments. These bays form numerous areas of rushes, Scirpus spp. in the foreshore and sedges, Carex spp, in the shallower water closer to the shoreline, (Photograph 124). They are backed by low clay or silty-clay banks often four to six feet above water level. The water level (as previously stated) was 711.9 feet on the date the Photograph was taken. At this point in time, slumping was not in evidence on this type (27b) shoreline and little effect would occur at the mean regulated level of 712.3 feet. At the 715 foot water level, flooding would be significant because of the low backshore relief. At the waterline, trees would be undercut and fall into the water. In the backshore, a zone of trees will be inundated. Inundated trees and driftwood will accumulate along the new shoreline.

The marsh zones will be reduced in width under the regulated water level regime.

Kiskitto Lake: The mean natural level of Kiskitto Lake is 693.5 feet. With regulation, the mean water level will be 697.0 feet, an increase of 3.5 feet. Since the lake level will be maintained independantly of Lake Winnipeg, the fluctuations will not be the same as that of the other outlet lakes. Water levels will be essentially constant with a maximum range from extreme low to extreme high of three feet. The natural range is 15 feet and the highest regulated level will be about four feet below the natural peak.

Since the shorelines will be subjected to less water level fluctuations and since the maximum levels will be decreased, there will be no shoreline erosion on Kiskitto Lake.

The reduction in the range of water fluctuations and an increment in mean water surface elevations will substantially reduce the marsh zones. These zones will not likely re-establish to any appreciable extent.

Nelson River West Channel: The Nelson River forms two channels downstream from the outlet of Lake Winnipeg at Lower Playgreen Lake. About 75% of the water flow is through the west channel. Regulation of Lake Winnipeg will result in short term fluctuations being more common than in the natural state. Discharges may rise or fall within one month by 40,000 cfs or more. These fluctuations will generally occur during the summer months and early winter (November and December). Table 49 summarizes the effects of regulation on discharges. Monthly maximum, median, minimum and range of discharges in the west channel of the Nelson River are shown in Figure 160.

The natural state shorelines were classified according to types as follows: 11- 8 miles, 13 - 86 miles (Photograph 123 and 125), 14 - 13 miles, 15 - 24 miles, 26 - 12 miles, 27 - 6 miles (Photograph 126), and 28 - 9 miles. This makes a total of 158 miles of shoreline. An important consideration on impact along the river is the erosive effect of water flow and ice abrasion. Accelerated erosion will occur particularly along the 12 miles of treed muskeg shoreline where over 14 square miles of treed muskeg backshore occurs (Reference 27). The low relief and loose binding nature of the low level areas may result in matted vegetation slumping into the water.

The portion of the west channel from Jenpeg to Kisipachewuk Rapids and to about two miles south, south-west of Whiskey Jack Narrows is shown on Figure 167. The 715 foot elevation contour has been designated as the boundary of inundation with regulation (Reference 28). If flooding occurs to this level, inundation will occur on 21, 821 acres of land surface in this portion of the west channel as shown on Figure 167. Typical treed muskeg vegetation covers 9,105 acres, 11,723 acres are forest covered, and 937 acres have no forest cover. The shoreline is typically bedrock controlled and lined with outcropping bedrock. The overburden is thin along most of the backshore but permafrost may be found where organic layers provide insulation.

The flooded forest (over 14 square miles) will die within two years. Dead standing trees will be evident in sheltered bays for an indefinite period. Trees exposed to erosive forces will be removed and collect along protected shorelines. A portion of the low willow shorelines (Type 28) will re-establish within a ten year period at the higher water levels. Shoreline Types 11, 13, 14 and 15 will display initial impacts to varying degrees relative to their respective overburden depths and tree cover. The subsequent stage of stabilization would be shortened by the accelerated rate of erosion caused by currents and ice abrasion in channel water regimes.

Nelson River East Channel: Nelson River east channel water discharges, in general, will be increased and higher discharges will be more prevalent. Extreme peak discharges will be reduced (Figure 161). Monthly variations from the mean monthly flows and the months during which they occur for the east channel are outlined in Table 50.

The east channel carries about 15% of the water discharge from Lake Winnipeg. The flow is divided into various channels separated by many long narrow islands. The shoreline types in general, are similar to those along the west channel shorelines. Percentage-wise, the mileage of Type 13 has decreased and that of Types 14, 15, 26 and 27 increased. Impact on these types (except Type 26) will not be as great as those on the west channel. Less flooding and erosion will occur than in the west channel because maximum discharge will be decreased with regulation.

Cross Lake: With regulation, Cross Lake will, in general, fall within the long term range of levels (Figure 166). The range of levels will be increased from 9.6 feet to 10.7 feet, but the regulated long-term average level will be reduced from 678.5 feet to 667.9, a difference of less than one foot. The seasonal dis-

tribution of lake levels will be changed with generally low levels in summer and higher levels in winter. Short term fluctuations (changes in water levels within one month) will be increased as shown in the data of Table 54.

Detailed Cross Lake natural and regulated monthly water levels are presented in Reference 29.

The 870 miles of Cross Lake shoreline is extremely irregular and most is made up of granite and gneissic granite. In order of decreasing extent, Types 13, 15, 14 and 11 comprise 800 miles of bedrock controlled shoreline. Most of the remainder is of Type 25 and 28 and only short stretches of Types 22, 26 and 31 occur.

Photograph 127 is typical of the generally low relief smooth surfaced shoreline of Type 13 shoreline. Commonly the relief rises ten feet in the first 100 feet of backshore. The typical Type 27 shoreline is illustrated in Photograph 126. Melted permafrost depressions frequent the Type 27 backshore areas (Photograph 128). These poorly drained areas are vegetated with sedges and grasses in the wet areas and willows and alders on the drier sites.

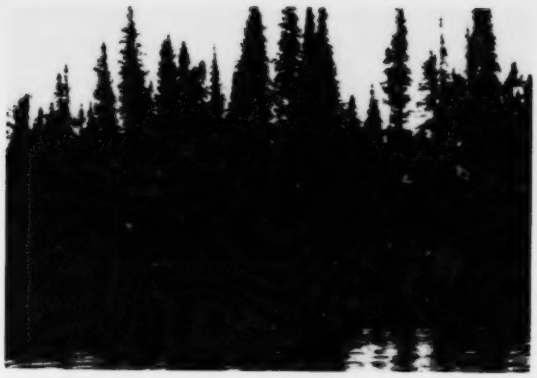
Cross Lake is characterized by wide spread marshes in the extensive protected bays between the outcrop promontories of the irregular shoreline (Photograph 129). Offshore stands of Sedges, Carex spp. predominates in the shallow water zones (two feet of water or less). Where water depths are two to six feet, bulrush, Scirpus spp., is the dominant plant (Photograph 130). Lower summer water levels will extend both the sedge and rush zones farther into the lake. Higher winter water levels would have little effect on marsh vegetation.

From information on the changing water level regime with regulation (Table 54) and from the shoreline description there is evidence that increased water levels are not of sufficient magnitude to cause more than slight soil erosion from the low bedrock shores.

PHOTOGRAPH 120 - Flooded Floating Fen, Sipiwesk Lake. Shrubs and most herbaceous vegetation had died. The area was extremely biologically active with waterfowl and wading birds of may species feeding on insects and amphibians attracted by the decaying vegetation.

PHOTOGRAPH 121 - Treed Muskeg Shoreline. This shows undercutting of soil causing forest slumping. Kiskittogisu Lake, September 4, 1973.

PHOTOGRAPH 122 - Black Spruce bog shows stunted tree growth and unhealthy coloration because of water saturation of root system (Kiskittogisu Lake).



PHOTOGRAPH 124 - Type 27b shoreline - Kiskittogisu Lake. Bay with an underlay of Agassiz sediments, supports rushes, in the foreshore and sedges, closer to the shoreline. The low clay bank supports a dense growth of black spruce.

PHOTOGRAPH 123 - Bedrock Shoreline backed by low clay bank supporting a closed forest of trembling aspen (Kisikittogisu Lake).

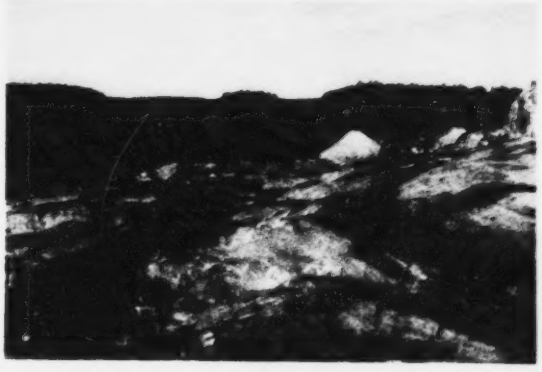
PHOTOGRAPH 125 - Nelson River west channel. Type 13 boulder shoreline. Low shoreline of glacial till with clay overburden backshore.

PHOTOGRAPH 126 - Nelson River west channel. Type 27 shoreline. Reworked glacial till at high water levels.

PHOTOGRAPH 127 - Cross Lake. A Type 13 shoreline. Low Relief Shoreline of smoothly glaciated bedrock. Aspen, and white birch, form the backshore forest.

PHOTOGRAPH 128 - Cross Lake. Backshore area of a Type 27 shoreline. Melted permafrost in the near backshore form depressions with alder, willow, sedge, and grasses, comprising the dominant vegetative species.

PHOTOGRAPH 129 - Cross Lake, offshore marsh zone. Marsh zones occurs in shallow water areas between outcrop promontories. Backshore willows and alders border the black spruce forest while sedges form dense offshore stands.



PHOTOGRAPH 130 - Cross Lake. Bulrush stand offshore of bedrock shoreline. Bulrush forms dense offshore vegetation in protected bay on lacustrine clay sediment in two to six feet of water.

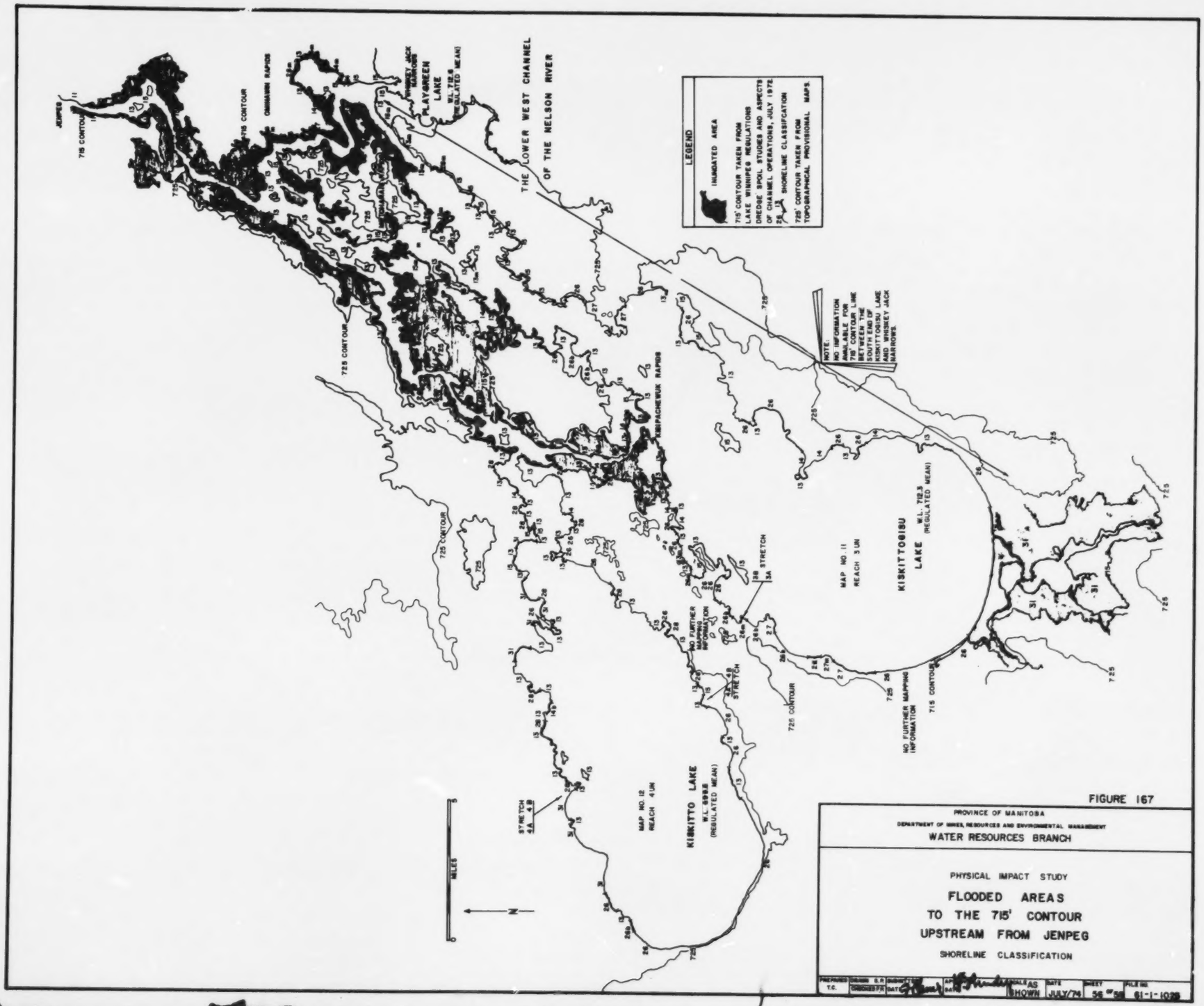

LEGEND
INUNDATED AREA
715' CONTOUR TAKEN FROM LAKE WINNIPEG REGULATIONS DREDGE SPOIL STUDIES AND ASPECTS OF CHANNEL OPERATIONS, JULY 1972.
SHORELINE CLASSIFICATION
725' CONTOUR TAKEN FROM TOPOGRAPHICAL PROVISIONAL MAPS.
NOTE:
NO INFORMATION AVAILABLE FOR 715' CONTOUR LINE BETWEEN THE SOUTH END OF KISKITTOGISU LAKE AND WHISKEY JACK NARROWS.
THE LOWER WEST CHANNEL OF THE NELSON RIVER
JENPEG
715 CONTOUR
725 CONTOUR
CHAMABINA RAPIDS
WHISKEY JACK NARROWS
PLAYGREEN LAKE
W.L. 712.8 (REGULATED MEAN)
KISKITTOGISU LAKE
W.L. 712.3 (REGULATED MEAN)
MAP NO. 11 REACH 3 UN
STRETCH 3A
STRETCH 3B
NO FURTHER INFORMATION
NO FURTHER MAPPING INFORMATION
MISSIPACHEWUK RAPIDS
KISKITTO LAKE
W.L. 698.8 (REGULATED MEAN)
MAP NO. 12 REACH 4 UN
STRETCH 4A - 4B
MILES
N

FIGURE 167

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

PHYSICAL IMPACT STUDY

FLOODED AREAS
TO THE 715' CONTOUR
UPSTREAM FROM JENPEG

SHORELINE CLASSIFICATION

PREPARED	DRAWN	C.H.	SUBMITTED		APPROVED	SCALE	DATE	SHEET	FILE NO.
Y.C.		ENGINEER	DATE		DATE	AS SHOWN	JULY/75	56 OF 58	81-1-102B

6.6.4 SUMMARY STATEMENT - LAKE WINNIPEG TO SIPIWESK LAKE: The area from Lake Winnipeg to Sipiwesk Lake (Upper Nelson River) that will be affected by the control structure at Jenpeg includes the Outlet Lakes, the West and East Channels of the Nelson River and Cross Lake. The Outlet Lakes at the north end of Lake Winnipeg are Lower (Southern) Playgreen, Upper (Northern) Playgreen, Kiskittogisu and Kiskitto.

Under natural conditons, water levels upstream or above Jenpeg are in general higher during summer months than during winter months. With regulation similar conditions will exist, but the mean water levels will, in general, be two feet higher than previously. Downstream from Jenpeg, Cross Lake levels with regulation, will in general be lower in summer and higher in winter. Short-term fluctuations in water levels will be greater both above and below Jenpeg.

The mean natural water level of Lower (Southern) Playgreen Lake is 711.9 feet. With regulation, the water levels will be confined within a narrower range of fluctuations (decreased by 4.9 feet). Mean levels will generally be higher than natural levels by 1½ feet, but peak levels will be reduced by 0.7 feet.

Low level shorelines predominate on Lower Playgreen Lake; treed muskeg, low sand beach, low willow and fen. Those shorelines will not be noticeably influenced by the changed water level regime.

The mean natural level of Upper (Northern) Playgreen Lake is 710.5. With regulation, the range of water levels will be decreased by 4.2 feet, but peak levels will be increased by 0.3 feet. Mean levels will be higher than natural levels by 2.1 feet.

Approximately one-half of Upper Playgreen Lake shoreline is low bedrock with a thin clay overburden. Erosion will be minimal on this shoreline. Most of the remaining shoreline is low level bedrock where backshore flooding will occur. Some slumping, caused by wave action on treed muskeg areas, will be evident.

In Upper and Lower Playgreen Lakes, both the later occurrence of peak water levels (early fall rather than mid-summer) and the reduction in the range of water levels will influence the existing and future marsh zones. Marshes will be reduced in extent under regulation.

The mean natural level of Kiskittogisu Lake is 709.7 feet. With regulation, both the mean and peak levels will be increased by 2.6 feet, while the range of water levels will be reduced by two feet.

About 1½ square miles, along the curved southern shoreline of treed muskeg and fen, will be flooded. The productivity of some of these areas will increase as they are reverted to the earlier plant successional stages. Organic shorelines will stabilize where the wave action has piled up the organic debris. Certain organic shorelines will rise with the raised water level thereby forming the new shoreline.

Flooding and slumping will occur in the many treed areas in bays along the west shore in the southern part. Less erosion and impact will be evident towards the northwest shoreline where bedrock outcrop is prevalent.

Flooding of undetermined extent will occur along the east shore where the low level topography consists of glacio-fluvial sand deposits. The majority of these beaches will be re-established at a high level within

a ten year period. The marsh zones will be reduced in width under the regulated water level regime.

The mean natural level of Kiskitto Lake is 693.5 feet. The regulated mean will be 697.0 feet, an increase of 3.5 feet. However, the highest regulated level will be approximately four feet below the natural peak. Kiskitto Lake levels will be regulated independently of Lake Winnipeg levels. Under regulating, the reduction in range of water level fluctuations (from 15 to 3 feet) will substantially reduce the width of the beach and marsh zones.

The West Channel of the Nelson River carries 85% of the water flow from Lake Winnipeg. With regulation, short-term fluctuations in discharge will be more common than in the natural state. Discharges within one month may rise or fall by 40,000 cfs. The 715 foot elevation contour has been designated as the boundary of inundation with regulation. If flooding occurs to this level, inundation will occur on 21,821 acres of land surface. Typical treed muskeg covers 8,105 acres, 11,723 acres are forest covered and 937 acres have no forest cover.

Bedrock shoreline will stabilize the soonest while sheltered bays will remain conjested with dead standing and fallen trees. Increased water flows and ice abrasion will cause many logs and debris to move downstream.

The East Channel of the Nelson River carries 15% of the water discharge from Lake Winnipeg. With regulation, water flow will be increased, but peak flows will be decreased from the natural state. Water levels will fall within the natural range. Impact effects will be minimal.

The mean natural level of Cross Lake is 678.5 feet. With regulation, the mean level will be 677.9, a reduction of 0.6 feet. The range of levels will be increased by 1.1 feet and the seasonal distribution of levels will be changed. These changes will have some effect on distribution of offshore vegetation. In general, the shoreline impact will be minimal.

6.7 LOWER NELSON RIVER - SPLIT LAKE TO HUDSON BAY

6.7.1 NATURAL STATE CONDITIONS - SPLIT LAKE TO HUDSON BAY:

The Lower Nelson River: The Nelson River, for the purposes of this study has been divided into the Upper and Lower divisions. The Lower Nelson includes Split Lake and all areas downstream (Figure 168).

The upstream end of the Lower Nelson flows through the precambrian rock in a typically irregular channel. This includes a section from Split Lake through to Kettle Rapids. Several miles of this channel have been obliterated by the Kettle power project which was completed in 1970.

In the vicinity of Long Spruce Rapids limestone replaces granitic rocks as the bed material. The river wears deeper and deeper into the limestone until at Limestone Rapids the Nelson is firmly entrenched in the sedimentary rock.

Below Limestone Rapids the river again rides the surface of the bedrock as the gradient lessens. Downstream of Kettle Rapids Dam ice accumulation is a major factor in forming the riverbanks (ice scoured shoreline). An ice scour zone extends up to 50 feet along the bank above the open water levels. This zone is vegetated with herbaceous plants, primarily sedges and grasses. High open-faces cliffs (vertical bedrock shorelines) are common to the stretches of limestone. Slumping shorelines are common to the areas downstream of Kettle Dam in fluvial, glacio-fluvial and till materials.

The Lower Nelson has been subdivided into six reaches each of which have similar features serving to identify it. Shoreline distances of each reach are as shown in Table 55.

Reach 1LN: Split Lake is defined as Reach 1 of the Lower Nelson River (Figure 169).

Split Lake is a widening of the Nelson River at its confluence with the Burntwood. The lake is set in a depression in rugged, bedrock controlled topography and has as a result an irregular shoreline and very many islands, a few of them several miles long. Portions of the area have recently been burnt, consequently the forest is largely regenerative with few mature trees.

The general backshore slope is as great as 20 feet in the first 150 feet. Bedrock is granite and diorite gneiss with more mafic banks and inclusions; the surfaces of outcrops are irregular, with many angular small boulders. Overburden is thin, and usually of lacustrine clays and silts, but is sometimes clayey till. Commonly Salix sp. grow to the water's edge. The forest on the slopes is dominantly Picea mariana with Picea glauca; in regeneration forests Populus tremuloides, Populus balsamifera and Betula papyrifera dominate.

All but 4 of the 262 miles of shoreline are bedrock controlled. The rock washed zones of Type 15 shorelines (134 miles) are narrow, only two to three feet wide, and discontinuous (Photograph 131) the 11 miles of Type 13 exhibit a wider water-washed zone.

Fifty seven miles of Type 14 occur. Beaches are 10 to 20 feet wide, are usually of sandy clay but sometimes of sand and cobbles, and are commonly over-

grown with dense to scattered Salix sp., Alnus sp. and Populus balsamifera shrubs. The slopes behind are similar to those of Type 15. Associated small stands of Carex spp., and Eleocharis sp., are common in protected indentations.

There are 56 miles of steep bedrock shoreline (Type 11) along Split Lake. They rise steeply out of the water, at slopes of more than 20 feet in a hundred feet, to as high as 50 to 60 feet above the lake. Shoreline outcrops are steep and smoothly rounded (Photograph 132). Overburden is typically very scant.

Types 24 and 28 comprise only 4 miles of shoreline. They are low Salix sp. overgrown flats at the heads of small inlets.

PHOTOGRAPH 131 - Split Lake, a Low Bedrock Controlled Shoreline (Type 15). The water-washed rock zone consists of two to three feet of outcrop and scattered till. Willows and alder frequent the maximum water line area.

PHOTOGRAPH 132 - Split Lake, a Steep Bedrock Shoreline (Type 11). The smooth water-washed zone is narrow. White Spruce, black spruce, and trembling aspen, form the backshore forest.

Reach 2LN: Still in the area of Precambrian rock, Reach 2 includes the channel between Split Lake and Gull Lake (Figure 170). Bedrock closely controls the topography even where bedrock does not in fact form the land-water interface. The channel form is very irregular as are the lakeshores involved. The terrain is of generally moderate relief and the uplands bend down to meet the river with a smooth slope. A low ice accumulation zone is in evidence here never being greater than perhaps 10 feet above the water level.

More than any other river reach investigated, Type 13 shorelines predominate (45 miles). The water-washed zone is narrow and shoreline vegetation is almost nil. A thin layer of overburden overlies a quickly climbing bedrock topography in the backshore. Major species in the closed forest are Picea glauca, Picea mariana, Populus tremuloides and Populus balsamifera.

Bedrock-controlled shorelines (Type 14) connect promontories. Vegetation, relief and drainage characteristics along the 6 miles of this shoreline are similar to the previously mentioned Type 13.

The only other component in this stretch is that of a marsh. There are only a couple of occurrences amounting to 4 miles of Type 28m. These marshes are narrow and do not extend far back from the water. As with the other shorelines, the backshore slopes quickly to the upland. The The marshes occur only in embayments where there seems to be an accumulation of alluvium.

Reach 3LN: Reach 3 begins downstream of the Kettle Rapids Dam and ends immediately above Limestone Rapids (Figures 170 and 171). The highest banks on the river are found in this section. Waters are very turbulent. The transition to marine deposited overburden is made near Kettle Rapids. The silt and clay banks are frequently open-faced, caused by toe erosion and melting permafrosted soils. The uplands are poorly drained and Treed with stunted black spruce.

Type 21 accounts for 38 miles of shoreline. Portions of this shoreline are very steep with the ice-scour zone extending some 50 feet, vertically, above the open water level of the river. The vegetation below the trim line is that of a seasonal steppe. The slope above the Trim line may extend another 100 feet to the uplands Picea glauca and Picea mariana combine to provide closed forest cover. A fairly dense understory of Alnus sp. and Salix sp. is usual.

The eleven miles of open-faced, slumping shorelines Type 25, constitute the remainder of riverbank in Reach 3 (Photograph 133). Local drainage valleys form V-shaped vegetated green areas in an otherwise clay-coloured riverscape. The slumps extend to the uplands and the only vegetation of consequence is that found in these small tributary gullies.

PHOTOGRAPH 133 - Lower Nelson River. A beach in the foreground and flatirons in the background indicate the diversity of landforms along the Nelson River.

Reach 4LN: The fourth reach of the Lower Nelson extends from Limestone Rapids to a point about ten miles upstream of the mouth of the Angling River (Figure 171). The river has eroded itself into the Paleozoic bedrock so that 90 percent of the bed and bank material is intact limestone. The river continues to flow in a deep valley with the banks rising quickly to the uplands.

In this reach the predominant shoreline type is vertical bedrock (Type 12). In most places along its 26 mile length, the height of ice-accumulation surpasses that of the bedrock cliffs. This induces either slumping in the banks above or an ice-scoured width of bank above the outcropping ledge. Closed coniferous (Picea glauca and mariana) forest continues in the backshore area.

The four miles of Type 25 shoreline occur with no apparent bedrock at the base of the slump.

Included also are three miles of ice-scoured bank. The height of the ice-scour zone is about 30-40 feet. Backshore slumping may be frequent.

Reach 5LN: Reach 5 like Reach 3 consists of two shoreline Types 21 and 25. Here backshore relief is less and the lower banks curve more gently to the river. Heavy run-off channels, completely dry, and well vegetated, enter the river at right angles at several locations between the Weir River and Deer Island. Heights of ice accumulation range from approximately ten feet at the downstream end to about forty feet at the upstream end near Angling River. There are 59 miles of ice-scoured bank (Photograph 134) and 14 miles of slumping marine deposits. The height of the vegetation on these shorelines has lessened somewhat and back on the uplands the growth is becoming more stunted. Permafrost gradually increases in areal distribution until it is continuous at the bottom end of the reach.

Reach 6LN: Reach 6 includes the channel from Deer Island to the Hudson Bay (Figure 172). The reduced relief found in the lower third of Reach 5 disappears and the uplands rise to some 70 or 80 feet above the river. By far the most common shoreline occurrence is again Type 25. These slumping areas are occasionally relieved by short stretches of Type 21 ice-scoured bank. Five miles of ice-scoured bank and 37 miles of active slumping shoreline comprise this reach.

PHOTOGRAPH 134 - Lower Nelson River; Ice Scoured Shoreline. Heavy annual ice accumulation frees a zone of all but annual vegetation. This is about five miles upstream of the mouth of the Angling River.

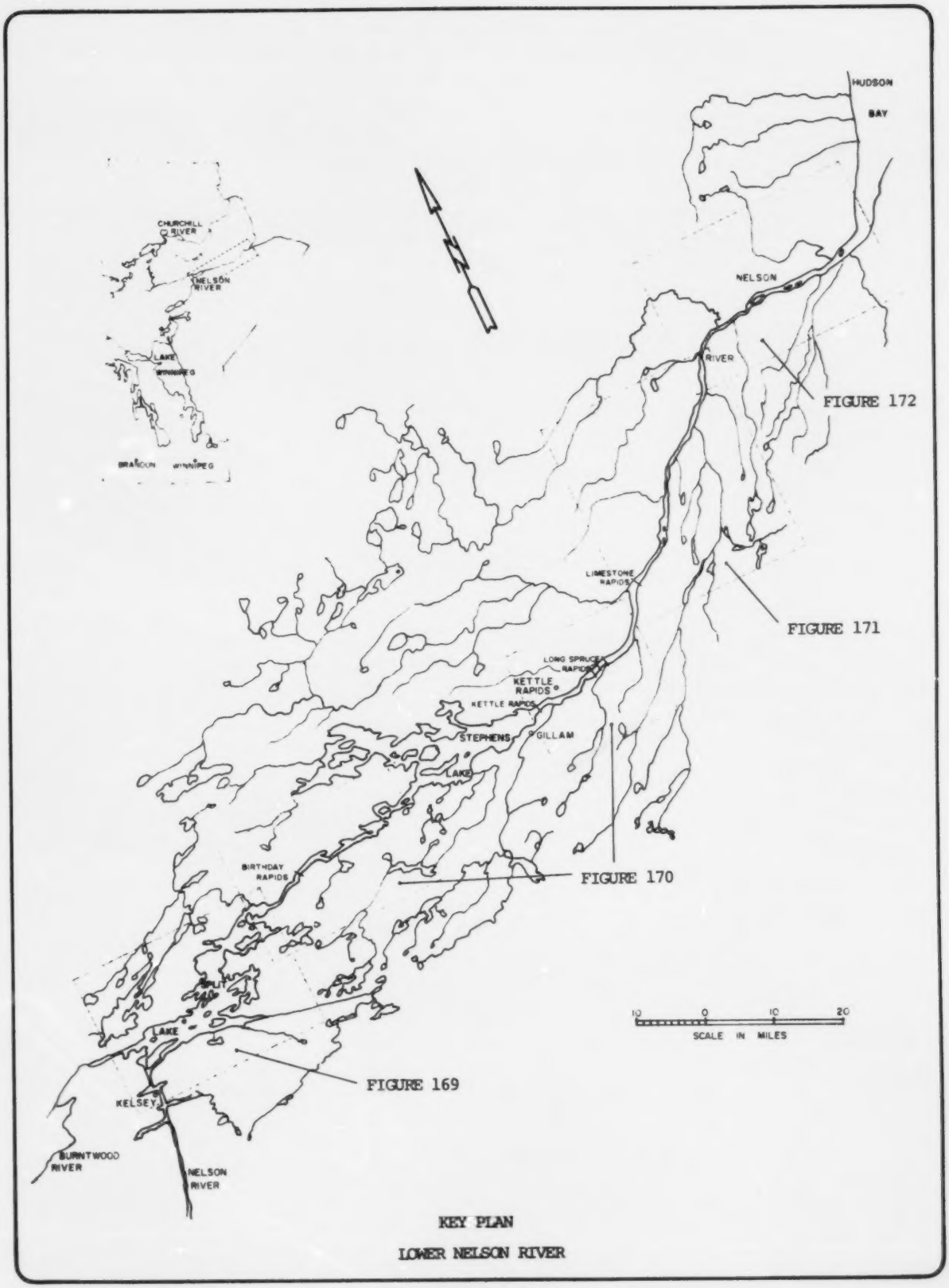
TABLE 55

LOWER NELSON RIVER

SHORELINE TYPES

CLASSIFICATION	11	12	13	14	15	21	22	23	24	25	26	27	28	31	TOTALS
Reach 1	56		11	57	134				3				1		262
2			45	6									4		55
3						38				11					49
4		26				3				4					33
5						59				14					73
6						5				37					42
TOTALS	56	26	56	63	134	105			3	66			5		514

NOTE: All distances in miles.



KEY PLAN

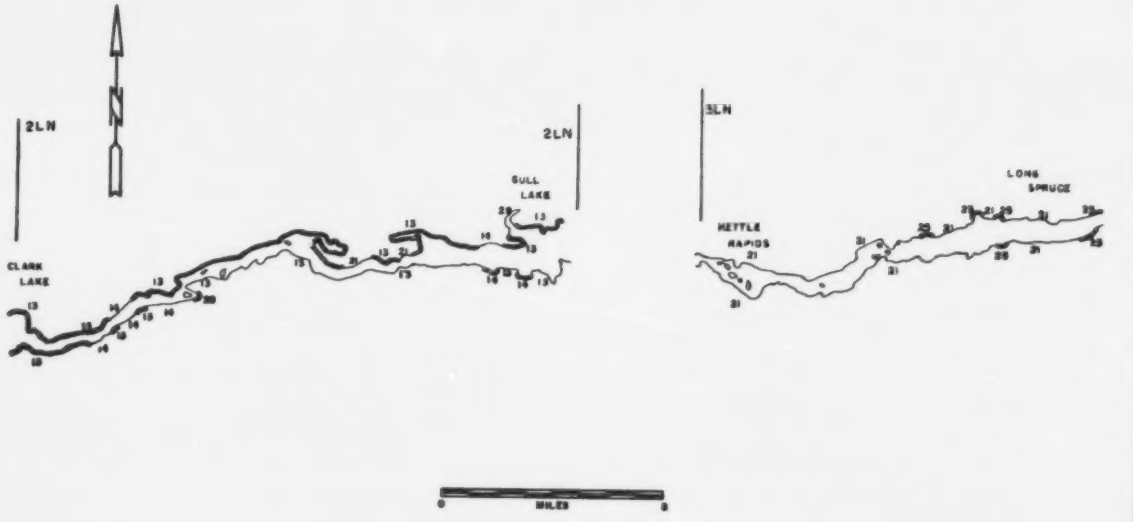
LOWER NELSON RIVER

FIGURE 168

REACH 1

LOWER NELSON RIVER - SPLIT LAKE

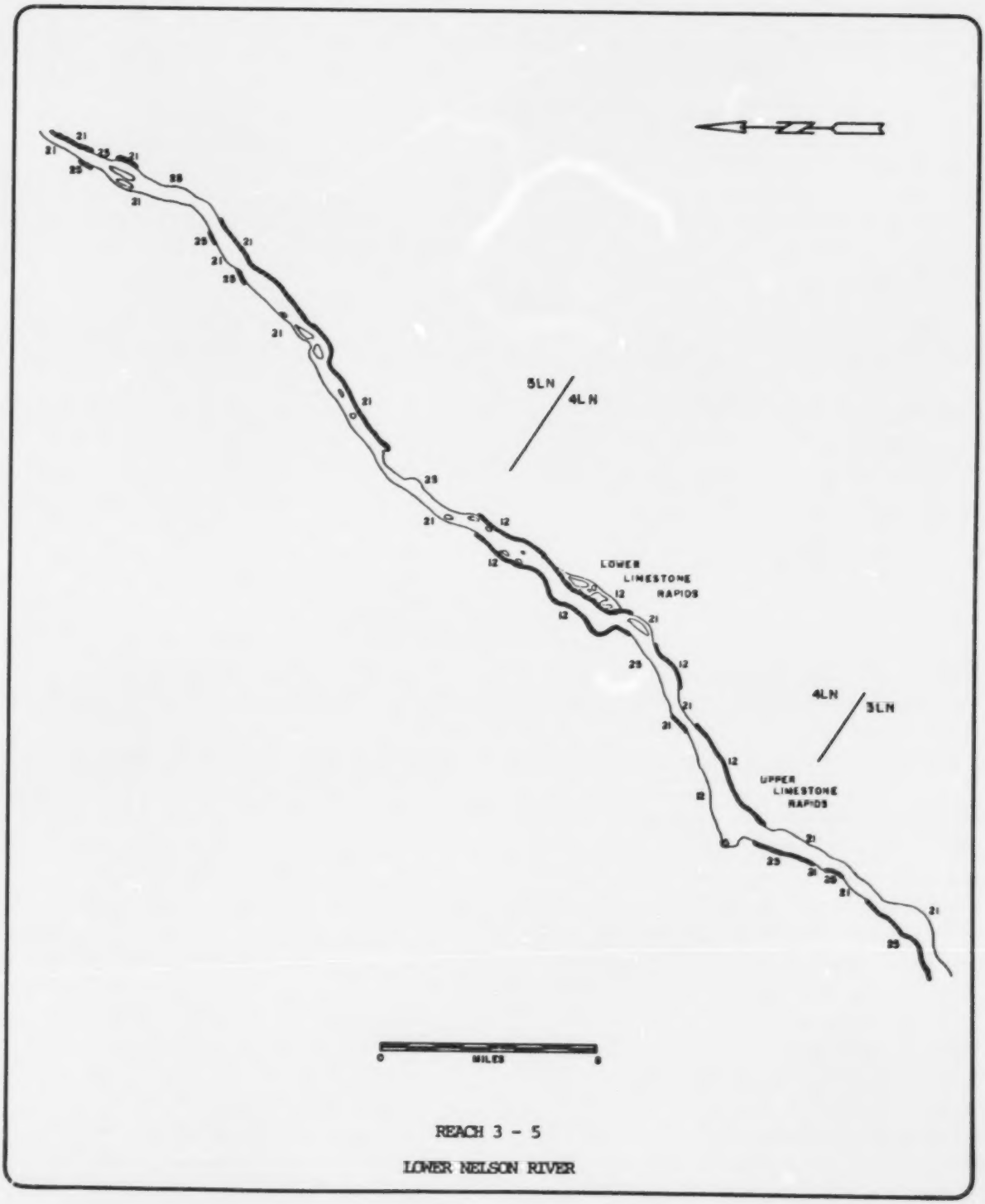
FIGURE 169



REACH 2 - 3

LOWER NELSON RIVER

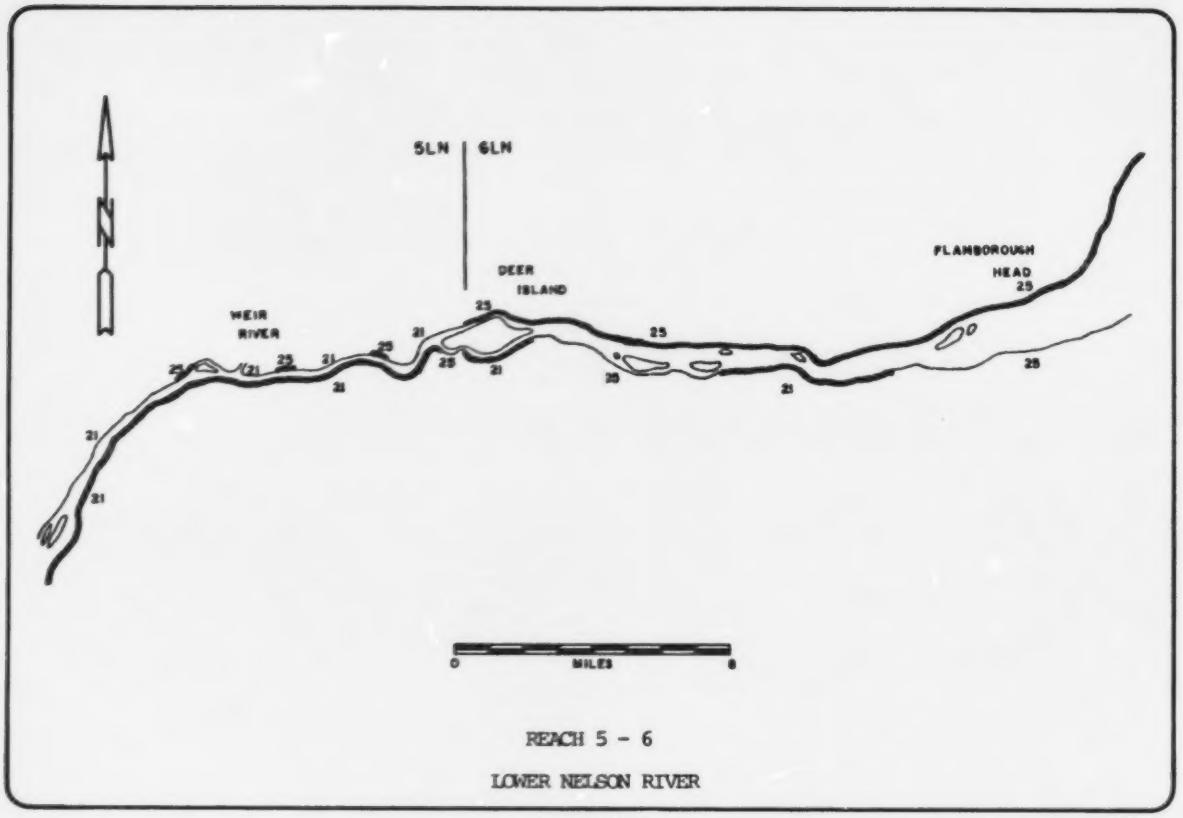
FIGURE 170



REACH 3 - 5

LOWER NELSON RIVER

FIGURE 171



REACH 5 - 6

LOWER NELSON RIVER

FIGURE 172

6.7.2 WATER LEVELS AND FLOWS - SPLIT LAKE TO HUDSON BAY: The Lower Nelson River will be subjected to the combined influence of regulated discharges from Lake Winnipeg and increased discharges from the Burntwood River. Discharges will be increased in most months, and only rarely will be less than the natural, unregulated flow. Figure 173 shows the natural (modified historic) and regulated discharge regimes for the Lower Nelson River at the outlet of Split Lake. In the natural state, highest discharges occur in mid-summer (June and July), dropping from there to mid-winter lows. Regulated discharges will be highest in mid-summer (except during low runoff years) dropping to late-summer lows, and increasing with rising power demand to higher levels in mid-winter. The average discharge will be increased by an amount equal to the mean Churchill River diversion, or by approximately 30,000 cfs. The change in winter flow regime may be of special importance to winter water levels on the lower portion of the river, as winter discharges in winter will be considerably increased. With regulation, discharges in winter will peak at flows as great as 140,000 cfs following early winter lows. Natural discharges for the same period are approximately 40,000 cfs less. This may be important in determining winter water levels with ice jamming on the lower channel. Mean monthly discharge for the November-to-April period is 105,000 cfs (almost equal to the open water mean) with regulation as compared to the natural mean of 63,000 cfs.

Also shown on Figure 173 are elevations at Split Lake (left scale on the figure) to correspond to the discharges from the lake, with a regulated maximum level of 554.5 in mid-summer and a natural minimum of 542.1 in

mid-winter. Levels will display the same type of fluctuation as discharge.

The effects on discharges in the reach from Split Lake to Hudson Bay will be modified somewhat by contribution from local inflow, depending on the location. Figure 174 shows the magnitude of local inflow into the river between Split Lake and the Bay. This contribution is roughly uniformly distributed over the whole length. Peak inflows as high as 12,000 cfs occur in June, and July, with lower values in the rest of the year, and lowest runoff in mid-winter as low as 1,500 cfs. This quantity represents approximately 3% of the natural discharge at Split Lake, and will contribute to Lower Nelson Flows with regulation in roughly the same way as in the natural state. For comparative purposes, therefore, natural and regulated discharges throughout the Lower Nelson River may be assumed to be the same as those at the outlet of Split Lake. Peak flow will be approximately 230,000 cfs at Hudson Bay compared to 216,000 cfs at Split Lake, an increase of about 5%.

The following tables summarize the parameters of discharge and levels at Split Lake and local inflow to the river below Split Lake.

TABLE 56

NELSON RIVER DISCHARGES AT SPLIT LAKE OUTLET

	Natural	Regulated	Change
Minimum	25,000 cfs (Jan, Feb, Mar)	60,000 cfs (May to Aug)	+35,000 cfs
Mean	80,000 cfs	110,000 cfs	+30,000 cfs
Maximum	173,000 cfs (July)	216,000 cfs (June)	+43,000 cfs
Long-term range	148,000 cfs	156,000 cfs	+ 8,000 cfs
Open-water mean	97,000 cfs	115,000 cfs	
Winter median	63,000 cfs	105,000 cfs	

TABLE 57

SPLIT LAKE ELEVATIONS

	Natural	Regulated	Change
Minimum	542.0 (Jan, Feb, Mar)	544.3 (May to Aug)	+ 2.3 feet
Mean	545.6	547.5	+ 1.9 feet
Maximum	551.6 (July)	554.4 (June)	+ 2.8 feet
Long-term range	9.6 feet	10.1 feet	+ 0.5 feet
Open-water mean	546.7	547.9	
Winter mean	544.5	547.2	

NOTE: Elevations are based on open water rating curve at Split Lake, Manitoba Hydro Drawing #7001-A-723

TABLE 58

LOCAL INFLOW - SPLIT LAKE TO HUDSON BAY

Minimum	150 cfs (Mar)
Mean	2,040 cfs
Maximum	12,000 cfs (June)
Open water mean	3,300 cfs
Winter mean	780 cfs

The changes in the level of the Nelson River from Split Lake to the head of the Kettle Reservoir and from Kettle Rapids to Hudson Bay due to regulation of Lake Winnipeg and the Churchill River Diversion were estimated for the flow conditions listed in the following table:

TABLE 59

FLOW CONDITIONS OF THE LOWER NELSON

Condition	Natural	Regulated	Change
Summer minimum	51,000 cfs	60,000 cfs	+ 9,000 cfs
mean	95,500 cfs	114,800 cfs	+ 19,300 cfs
maximum	173,000 cfs	216,000 cfs	+ 43,000 cfs
Winter minimum	25,000 cfs	64,000 cfs	+ 39,000 cfs
mean	66,600 cfs	101,000 cfs	+ 34,400 cfs
maximum	117,000 cfs	141,000 cfs	+ 24,000 cfs

The changes in water level associated with these changes in flow were computed for various locations from open water rating curves and water surface profiles supplied by Manitoba Hydro. These changes are listed in the following table:

TABLE 60

INCREASE IN LEVEL OF NELSON RIVER DUE TO REGULATION AND DIVERSION - SPLIT LAKE TO HUDSON BAY

Location	Increase in Level for Specified Condition - Feet					
	Summer			Winter		
	Min	Mean	Max	Min	Mean	Max
Split Lake Outlet	0.6	1.2	2.8	2.5	2.2	1.6
Below Kettle Rapids	0.6	1.3	3.0	2.7	2.4	1.7
Kettle Rapids to Long Spruce	0.4	0.8	1.8	1.6	1.4	1.0
Long Spruce	0.3	0.6	1.4	1.2	1.1	0.8
Long Spruce to Upper Limestone	0.4	1.0	2.1	1.9	1.7	1.2
Upper Limestone	0.3	0.6	1.4	1.2	1.1	0.8
Upper Limestone to Lower Limestone	0.7	1.4	3.2	2.9	2.6	1.8
Lower Limestone	0.4	1.0	2.1	1.9	1.7	1.2
Lower Limestone to Gillam Island	1.0	2.1	4.7	4.3	3.8	2.6
Gillam Island	0.4	0.8	1.7	1.6	1.4	1.0
Mean values	0.4	1.1	2.4	2.2	1.9	1.4

Regulation of Lake Winnipeg and the Churchill River Diversion have the effect of raising the river level roughly two feet for most conditions.

The winter water levels for any discharge under normal ice conditions are typically 5 to 10 feet higher than summer water levels, and may be some 20 to 40 feet higher in the case of severe ice jam conditions. Since the regulated mean winter discharge is roughly equal to the regulated mean summer and natural mean summer discharge, winter ice levels will almost invariably be higher than summer water levels.

The Long Spruce Generating Station now under construction will alter water levels and ice conditions. However, this has not been considered in this study.

In summary, for the purpose of this study it has been assumed that all water levels will be raised roughly two feet and that winter ice levels will be higher than summer water levels.

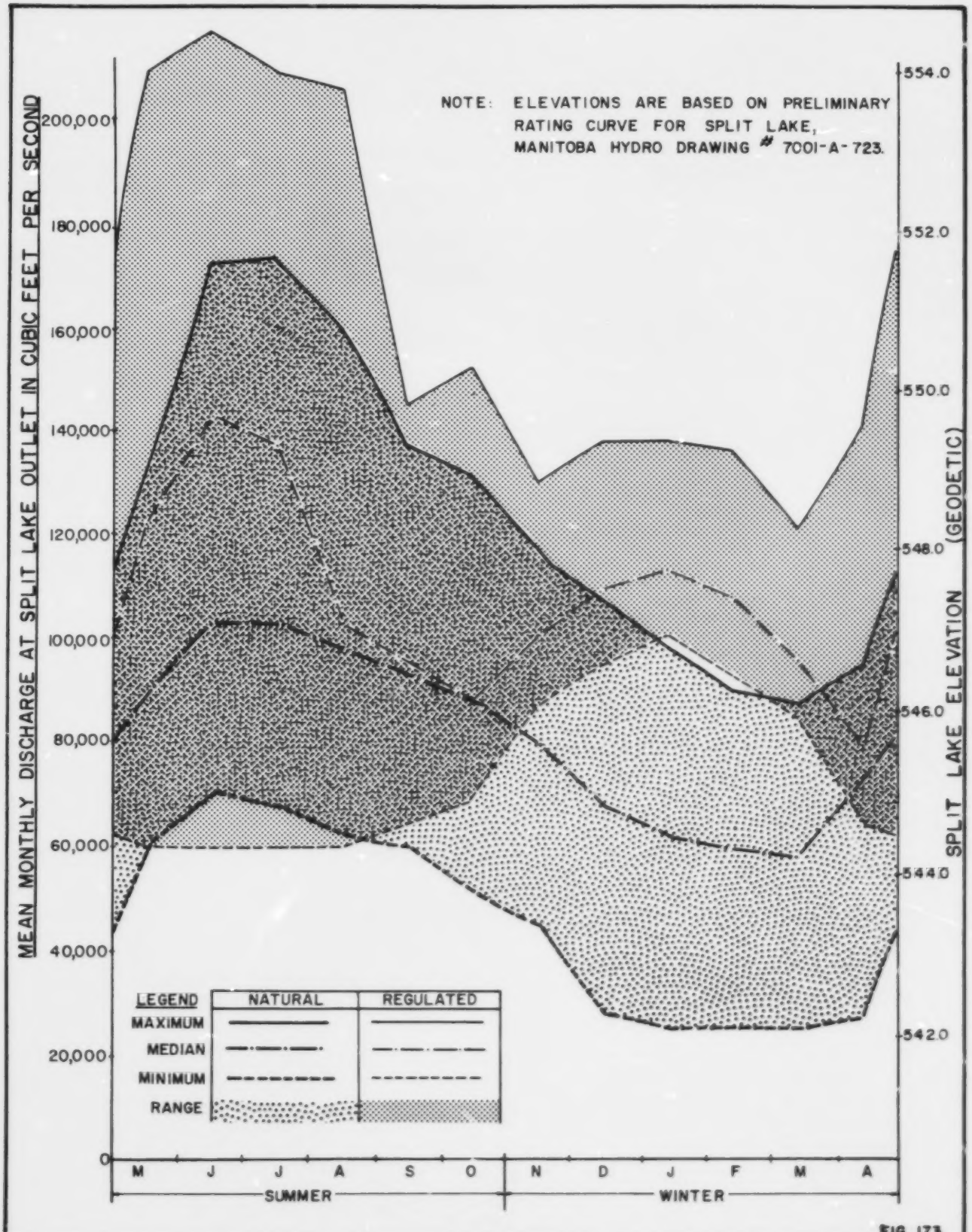


FIG. 173

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD PHYSICAL IMPACT STUDY DISCHARGES IN THE NELSON RIVER AT THE OUTLET OF SPLIT LAKE
PREPARED L.B. DRAWN S.P. CHECKED F.P. SUBMITTED DATE	APPROVED DATE SCALE AS SHOWN DATE JAN/74 SHEET 57 OF 58 FILE NO. 61-1-1025

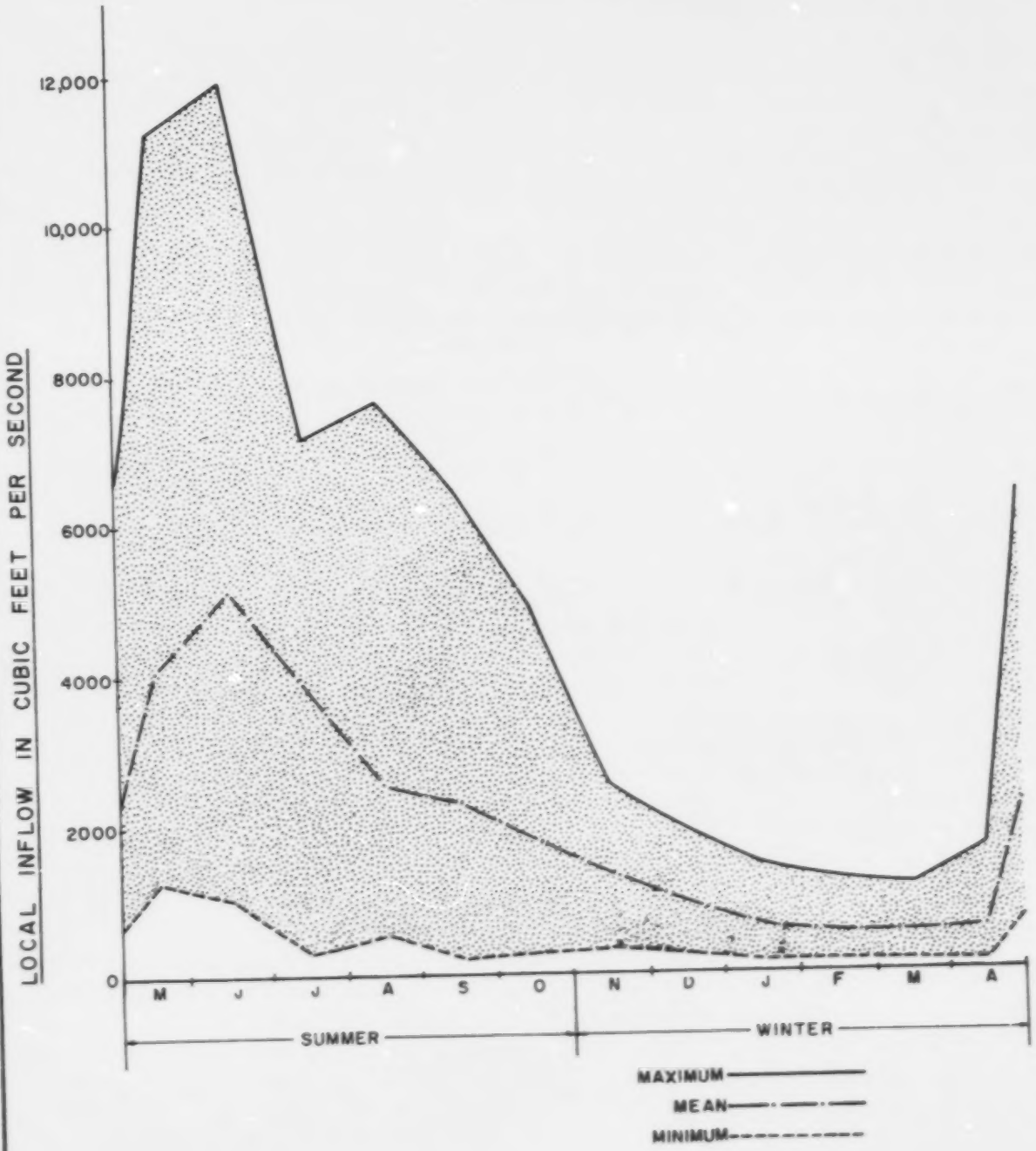


FIG. 174

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
LOCAL INFLOW TO THE NELSON RIVER
SPLIT LAKE TO HUDSON BAY

PREPARED	DRAWN	SUBMITTED	APPROVED
L.B.	S.P.		
	CHECKED F.P.	DATE	DATE

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	JAN/74	58 OF 58	61-1-1028

6.7.3 IMPACTED STATE CONDITIONS - SPLIT LAKE TO HUDSON BAY: The Lower Nelson River including Split Lake and areas downstream to the estuary at Hudson Bay will be affected by the increased discharge of water from the Churchill River Diversion, about 30,000 cfs and by the regulation of Lake Winnipeg. In terms of water levels, this represents an increment of approximately two feet during the open water season. Under regulation, the winter ice levels will continue to be higher than the summer water levels. Impact on the shoreline types for each reach is discussed relative to the different classifications.

The general impact processes are as discussed in "Impact Process Statement for Shorelines" and for "River Channels with Increased Flows", Sections 5.4.1 and 5.4.4.

Reach 1: Under natural conditions the Split Lake level mean is 545.6 feet and under regulated conditions will be 547.5, an increase of 1.9 feet. The increase in the maximum level with regulation will be 2.8 feet as shown in Table 57.

Of the 262 miles of shoreline about one-half (134 miles) is Type 15 - Low Bedrock Controlled. Under a two foot increment, the water-land interface will receed approximately 10 to 20 feet up the slope.

The 57 miles of Type 14, bedrock controlled shoreline with overburden beach have backshore slopes similar to Type 15. Shoreline recession would, therefore, be similar. Inundated beaches will be reformed at the higher elevations within a ten year period.

Type 14 and 15 shorelines will have debris (eroded trees) along the shorelines. This debris would originate from the lakeshore itself and upstream flooded rivershores.

The 57 miles of steep bedrock shoreline, Type 11, rise steeply to heights of 50 to 60 feet above the lake level. Since these are granitic rock shorelines, little to no impact would occur at the two foot increased water level.

The 11 miles of low bedrock shoreline, Type 13, will be slightly affected by erosion of thin overburden and sparse vegetation. Being headlands, the wave action will keep the shoreline free of debris.

Four miles of Split Lake consists of Type 24, Low Alluvial Shoreline, and 28, Low Willow Shoreline. Flooding would be severest along these shorelines due to their low relief. Under diversion conditions these shorelines will be characterized by the standing and beached debris.

Reach 2: In the natural state, the highest discharges at the outlet of Split Lake occur in mid-summer (June and July) dropping from these to mid-winter lows. With regulation, discharges will be highest during mid-summer, dropping to late summer lows, and increasing with rising power demand to higher levels in mid-winter.

Of the 55 miles of shoreline, 45 miles are Type 13, low bedrock. Shorelines of this type will be little affected and shoreline interface will not retreat significantly at the expected low-level flooding.

Horizontal flooding will be greatest along the four miles of Type 28. Along these shorelines the marshes are narrow and the backshore slopes quickly upwards. The willow border will re-establish itself at a higher bank elevation. Marshes will be inundated and may be re-established.

These protected shorelines will be characterized by standing and beached debris.

Reach 3: In this reach, the change in winter flow regime may be of special significance to winter water levels where ice jams occurred under natural conditions in fast flowing areas below Kettle Rapids. Winter levels up to thirty feet above summer maximums are reached. With regulation, flows as high as 140,000 cfs will follow early winter lows. The effect of increased velocities on the ice surcharge phenomenon is at present unknown.

Erosion will be of no consequence on Type 21 shorelines as the raised summer water levels will fall within the ice scour zone. Under higher winter levels, the scour zone will be extended further up the bank. The steep relief and overburden of Type 25 makes this shoreline very vulnerable to all water level increments. Under diversion conditions, shoreline erosion will be accellerated. However, a natural shoreline will be achieved shortly after flooding.

Reach 4: The vertical bedrock shorelines (Type 12) of this reach will not be affected by raised open water levels. Higher winter levels, however, may increase the slumping of overburden that mantles the bedrock cliffs.

The impact on the remaining shorelines, Type 21 and 25, is as discussed in Reach 3.

Reach 5 and 6: As both these reaches are characterized by Types 21 and 25 shorelines, the impacts will be similar. The shoreline impact is as discussed in Reach 3.

Under diversion conditions, horizontal flooding will be greatest along the many tributaries feeding into the Lower Nelson. This will subsequently result in the inundation of alluvial flats at the river mouths. Consequently, the graminoid zone (sedges and grasses) will be reduced in width. These zones will be re-established with the deposition of alluvium.

6.7.4 SUMMARY STATEMENT - SPLIT LAKE TO HUDSON BAY: The Lower Nelson includes Split Lake and the Nelson River downstream of Split Lake to the estuary at Hudson Bay with the exclusion of the Kettle Generating Station forebay.

The shorelines of Split Lake (262 miles) are predominatly bedrock with a few miles of beaches and marshes in protected embayments. Backshore overburden is shallow. The Nelson River downstream of Kettle dam to Hudson Bay flows through an area of Precambrian granites and paleozoic limestones. Thick overburden materials are occasionally permafrosted, resulting in shoreline instability. Headwater uplands are characterized by closed blackspruce forests while the vegetation is tundra-like in downstream uplands.

River channels do not exhibit the variety of shoreline types typical of the lakes; these subarctic river channels are characterized by steep bedrock shorelines, ice scoured shorelines or else slumping overburden shorelines. There are some 252 miles of shoreline downstream of Kettle dam.

Channel waters are turbid and turbulent. Rapids frequent the entire route.

Under regulation, the Lower Nelson will be subject to the combined influence of regulated discharges from Lake Winnipeg and increased discharges from the Burntwood

River. Mean open water levels will be raised roughly two feet while winter ice levels will continue to be higher than the summer levels.

Under regulation, the overburden and vegetation of the bedrock shorelines will be removed within the higher water-washed zone. In general, on Split Lake the water-land interface will retreat some 10 to 20 feet horizontally on bedrock and bedrock controlled shorelines.

Protected bedrock shorelines and embayments, particularly Split Lake, will remain atypical due to the accumulating debris (fallen trees). This debris will originate from Split Lake shorelines and impacted upstream river channels.

Along the Lower Nelson flooding will be greatest horizontally within the alluvial and marsh type shorelines. Marsh zones will be initially reduced in extent.

The shoreline types typical of Manitoba subartic rivers: vertical bedrock, ice scoured and slumping overburden, will not be greatly affected under raised water levels. Initially erosion will be accelerated on slumping overburden shorelines; these shorelines will shortly achieve a natural condition.

7.0 SUMMARY OF IMPACT PROCESSES AND CHARACTERISTICS

In 1972, the impact of altered water regimes was surveyed at 9 locations of varying ages:

Site	Date and Development
Sipiwesk Lake	1960 flooded 8'
Kelsey Forebay	1960 flooded < 53'
Kettle Forebay	1970 flooded < 98'
Reindeer Lake	1942 flooded 7'
Laurie River Forebay	1952 flooded < 52'
Cedar Lake	1964 flooded 12'
Lac Seul	1929 flooded 10'
Russell	1952 flooded 10'
Butnau River	1968 diversion
Ogoki River	1941 diversion
Root River	1957 diversion

At all sites, with the partial exception of Reindeer Lake, unstable conditions existed as lakes and channels were actively adjusting to the imposed artificial water regime.

The following summaries were prepared from surveys made in 1972 to indicate the nature and forms of re-adjustment. More detailed data is available for each location where specific information is required for study components.

Sipiwesk Lake, Upper Nelson River -

Development: -Shoreline flooded 1960 as pondage for Kelsey Generating Station.
-Mean increase in lake level: 7.5 feet.
-Mean annual level fluctuation: 4.8 feet.

Preliminary Impact: Total flooded area - < 10 square miles distributed around 1100 miles of shoreline.

Processes of Re-Adjustment:

(1) shoreline vegetation killed to maximum water level, predominantly remaining in place.
(2) increased shoreline erosion and nearshore turbidities.

Distribution of Impact:

none - 5% of shoreline; predominantly steep rock outcrop areas (Photograph 135).

slight - 10% of shoreline; a narrow band of dead trees formed.

moderate - 35% of shoreline; vegetation killed and erosion, (Photograph 136).

severe - 50% of shoreline; erosion and flooding extending inland particularly in embayment areas (Photographs 137, 138 and 139).

Kelsey Forebay - Nelson Channel -

Development: -Flooded during summer of 1960.
-Mean increase in level: 53 feet.

Preliminary Impact: Total flooded area less than 5 square miles, distributed unevenly over 150 miles of shoreline.

Processes of Re-Adjustment:

(1) solifluction of unconsolidated till where water has risen well above the previous stable shoreline.
(2) near the upper end of the channel, banks exhibit severe undercutting (Photograph 140).
(3) shoreline vegetation was killed to the maximum water level, remaining in place except in areas of slumping and instability (Photograph 141).

(4) increased shoreline erosion with resultant higher turbidities were sampled next to unconsolidated overburden shorelines. Midstream islands were also rapidly eroding.

Distribution of Impact:
slight - 20% of shoreline, dead vegetation only (Photograph 142).
moderate - 40% of shoreline with dead vegetation and some erosion.
severe - 40% of shoreline mainly in embayments, dead vegetation, erosion, undercutting and solifluction (Photograph 143).

Kettle Reservoir -
Development: -The Kettle forebay was raised in two stages in the falls of 1970 and 1971.
-The increase in level varies from a maximum of 98 feet at the dam to a minimum of 43 feet at the base of Gull Rapids
-Mean annual fluctuation is estimated to be 5 feet.

Preliminary Impact: -Flooded area approximately 125 square miles.
-Mean inland extent of foreshore flooded approximately 0.6 miles.

Processes of Re-Adjustment:
(1) undercutting due to wave action on high till banks (Photograph 144).
(2) extensive melting of permafrost throughout the reservoir resulting in widespread areas of instability and slumping (Photograph 145).
(3) large area of flooded vegetation - much of it not yet dead with floating peat islands in embayments (Photograph 146).
(4) severe erosion of overburden banks and midstream islands.

Distribution of Impact: -nil - 5% bedrock shoreline,
-severe - 95% vegetation flooded, severe solifluction and erosion.

Reindeer Lake -
Development: -Reindeer Lake was first regulated in 1942. Average increase in levels 7 feet.
-Maximum fluctuation is 4 feet. Mean fluctuation 2 feet.

Preliminary Impact: A very narrow band of flooded shoreline. Flooded area is less than 10 square miles distributed over several thousand miles of shoreline.

Processes of Re-Adjustment:
(1) new beaches being formed on granular materials at north end of lake (Photographs 147 and 148).
(2) driftwood piled at both ends of the lake; most trees (greater than 70%) have fallen in narrow (5') shoreline strip (Photograph 149).

Distribution of
Impact: -Bedrock control exhibited in the southwest end of the lake and flooding extends less than 5 feet inshore.
-Flooding extends farther (10 - 20 feet) into embayments towards the northern end of the lake where the topography is generally lower.

Laurie River #1 and #2 -
Development: -The Laurie River plants were constructed and their forebays filled in the early to mid-fifties.
-The heads at both plants

are 50 - 55 feet indicating the maximum depth of flooding.

Preliminary Impact: Much of the bedrock shoreline has washed free of overburden and stabilized. Where till forms the banks, some erosion and nearshore turbidity is noticed. Embayments contain standing dead vegetation (Photograph 150).

Cross and Cedar Lakes -

Development: -Flooded behind the Grand Rapids Project in 1964 and 1965.
-The head of the plant is about 125 feet which raised the level of Cross Lake by 25 feet, Cedar Lake by 12 feet and S. Moose Lake by 5 to 7 feet.
-The mean fluctuation is 8 feet with a maximum of 10 feet.

Preliminary Impact: Total flooded area 800 - 900 square miles, much of it over the prehistoric delta area.

Processes of Re-Adjustment:

(1) very little subsidence,
(2) new marsh and delta areas establishing slowly with standing dead vegetation in embayments,
(3) some flooding outside of dyked area due to porosity of underlying limestone.

Distribution of

Impact: -nil - 5% of shoreline is limestone cliffs (primarily Moose Lake).
-moderate - severe - 95%. The least impact is noted in the forebay area where the shoreline has been cleared and the debris removed. Cross and Cedar Lake show severe impact in terms of vegetation but not shoreline erosion (Photograph 151)

Lac Seul -

Development: -The level of Lac Seul was raised by approximately 10 feet in 1929.
-The mean annual fluctuation is 8 feet.
-Although no net level change resulted, in 1957 water from Lake St. Joseph was diverted into Lac Seul.

Preliminary Impact: Many shorelines are lined with dead trees trunks lying in widths up to 100 feet offshore. Few trees remain standing. Impact is negligible in frequent bedrock areas.

Processes of Re-Adjustment:

(1) sand is eroding from banks along the diversion and on the west end of the lake (Photograph 152).
(2) sand moved by wave action deposits near protruding stumps producing sand bars.
(3) fluctuation of 8 feet has resulted in a broad offshore development.

Distribution of Impact: Presently the impact is moderate consisting mainly of driftwood piling.

Butnau River Diversion -

Development: -Diversion put into operation in October of 1968.
-Flow varies from almost 0 cfs up to 900 cfs.

Preliminary Impact: The diversion channel length is 2.5 miles between Cache Lake and the Kettle River.

Processes of Re-Adjustment:

(1) severe undercutting and erosion as channel widens (Photograph 153).
(2) large blocks of partially frozen peat fall into the river after melting of the underlying permafrost materials adjacent to water.

Distribution of Impact: The complete diversion, omitting a short rip-rapped section (Photograph 154) is actively slumping or eroding. Dead vegetation amounts to that which has fallen into the river with the collapsing banks.

The Ogoki Reservoir and Diversion -

Development: -Reservoir was filled in 1942 - 43.
-The channel was flooded by almost 42 feet.
-The mean annual water level fluctuation is 63 feet.
-First diversion flow was in 1943.
-Average diversion flow approximately 4000 cfs.

Preliminary Impact: Major shoreline flooding occurred in the valley of the Ogoki River, now called the Ogoki Reservoir, and on Mojikit Lake. The 25 miles diversion channel, the Little Jackfish River now carries up to 20 times the former normal flow.

Processes of Re-Adjustment:

(1) in the reservoir there is very little evidence of widespread erosion as a protected zone of dead vegetation lines the area in widths up to 300 feet (Photograph 155).
(2) along the diversion route initial downcutting through glacial deposits has occurred to the bedrock surface (Photograph 156).
(3) extensive active undercutting and slumping persists in areas of high lacustrine clay banks as the channel adjusts in width (Photograph 157).
(4) deposition of eroded material has formed a delta in Ombabika Bay that extends for several miles offshore (Photograph 158).

Distribution of Impact:

Reservoir - Impact has been severe on vegetation and extends throughout 95% of shoreline. New stable shorelines are not evident with the exception of outcrop areas.

Diversion - Impact on the first half of the channel between Majikit Lake and Zigzaq Lake is slight.

The lower segment of the channel is severely impacted as is the bay on Lake Nipigon.

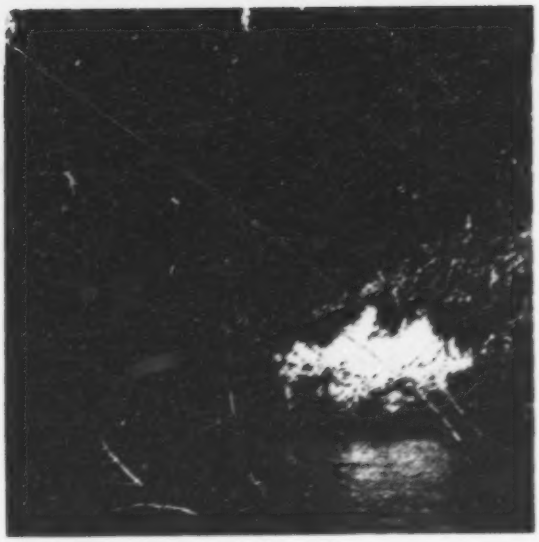
PHOTOGRAPH 135 - Sipiwesk Lake - Flooding effects are negligible along steep outcrop shorelines.

PHOTOGRAPH 136 - Sipiwesk Lake - Wave action undercuts and erodes clay banks.

PHOTOGRAPH 138 - Sipiwesk Lake - Flooded white birch in an embayment.

PHOTOGRAPH 137 - Sipiwesk Lake - Offshore flooded trees in an embayment on the south side of the lake.

PHOTOGRAPH 139 - Sipiwesk Lake - An aerial view: Floating islands in an inundated backshore.



PHOTOGRAPH 140 - Kelsey Forebay - Eroding clay shoreline.

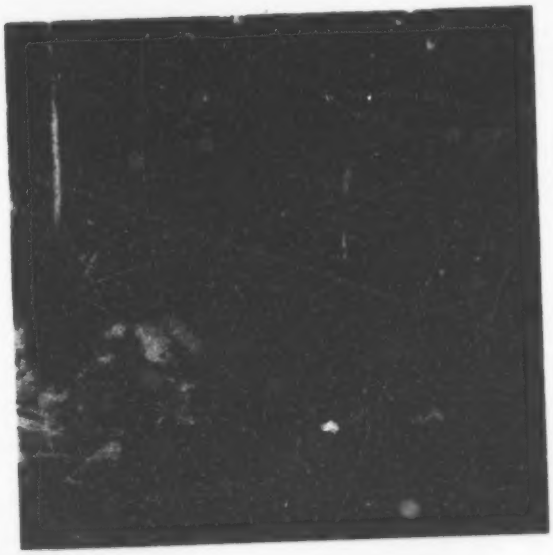
PHOTOGRAPH 142 - Kelsey Forebay - About 20% of the shoreline is bedrock outcrop with little damage resulting.

PHOTOGRAPH 141 - Kelsey Forebay - An inundated island.

PHOTOGRAPH 143 - Kelsey Forebay - Flooded embayments are vulnerable to extensive damage.

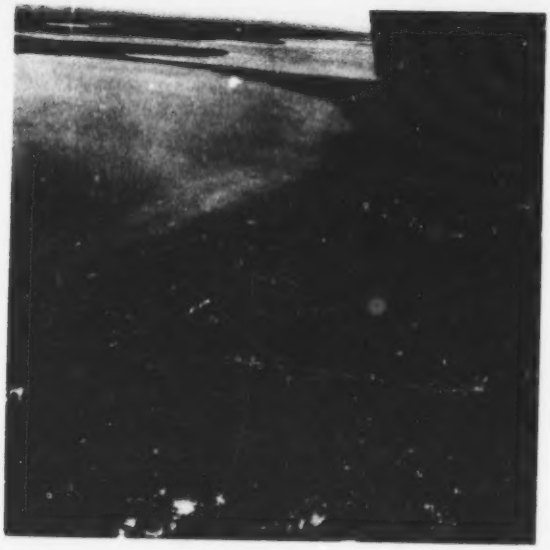
PHOTOGRAPH 144 - Kettle Reservoir - Bank failure resulting from wave action and melting permafrost.

PHOTOGRAPH 146 - Kettle Reservoir - An uncleared shoreline in a flooded embayment.



PHOTOGRAPH 145 - Kettle Reservoir - Melting permafrost is the major cause of bank instability. This ice lense is in sand.

PHOTOGRAPH 147 - Reindeer Lake - Re-establishment of a low relief beach on Long Point is taking place slowly.



PHOTOGRAPH 148 - Reindeer Lake - Shorelines stabilize quickly along post-glacial beaches.

PHOTOGRAPH 150 - Laurie River - Protected areas of reservoirs, flooded in the 1950's, with large amounts of trees still standing in the forebay,

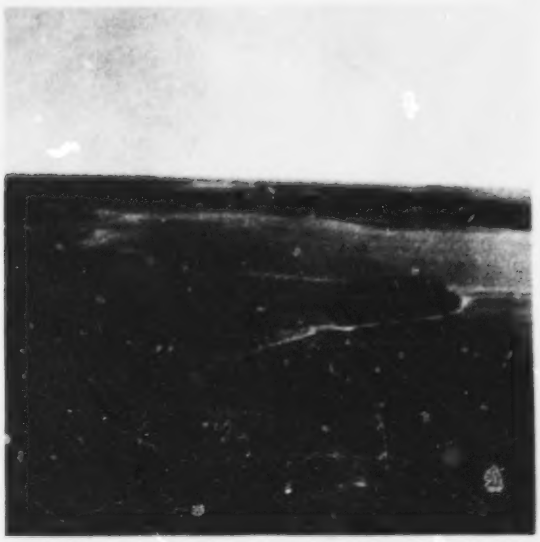
PHOTOGRAPH 149 - Reindeer Lake - Accumulated driftwood retards normal shoreline development.

PHOTOGRAPH 151 - Cedar Lake - Flooded trees in Napanee Bay.

PHOTOGRAPH 152 - Lac Seul - Unstable bank conditions on the 15 year old Root River Diversion.

PHOTOGRAPH 154 - Butnau Diversion - The railway crossing protected by extensive riprapping.

PHOTOGRAPH 153 - Butnau Diversion - The channel banks are being undercut causing huge chunks of peat to fall into the river.



PHOTOGRAPH 155 - Ogoki Diversion - The reservoir behind Summit Dam. Note the wide waterwashed zone.

PHOTOGRAPH 156 - Ogoki Diversion - Slumping continues as the river attains an equilibrium width. Note deposition in foreground. Boulder-paving of the riverbed has virtually halted the downcutting of the Little Jackfish River.

PHOTOGRAPH 157 - Ogoki Diversion - The widening process involves undercutting, subsidence and erosion. Note that the banks are devoid of vegetation.

PHOTOGRAPH 158 - Ogoki Diversion - The eroded bank material is deposited in a delta extending several miles into Ombabika Bay, Lake Nipigon.

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APPENDIX A

TABLE 61

GLOSSARY OF LATIN TERMS

LATIN NAME	COMMON NAME
Abies balsamea	Balsam Fir
Achillea sp.	Yarrow
Alnus sp.	Alder
Andromena glaucophylla	Bog-rosemary
Aralia nudicaulis	Wild Sarsaparilla
Arctostaphylos uva-ursi	Bearberry
Aster spp.	Aster
Astragalus sp.	Milk-vetch
Betula glandulosum	Drawf Birch
Betula papyrifera	Paper Birch
Campanula sp.	Bellflower
Carex sp.	Sedge
Cassandra sp.	Leather Leaf
Cladonia rangiferina	Reindeer Moss
Clintonia borealis	Bluebead Lily
Cornus canadensis	Bunchberry
Cornus stolinifera	Dogwood
Drosera intermedia	Sundew
Eleocharis sp.	Spike-rush
Empetrum nigrum	Crowberry
Epilobium angustifolium	Fireweed
Equisetum sp.	Horsetail
Gramineae	Grass
Juniperus Communis	Juniper
Kalmia polifolia	Bog-laurel
Larix laricina	Tamarack
Ledum groenlandicum	Labrador Tea
Lemna sp.	Duckweed
Linnaea borealis	Twinflower
Lycopodum sp.	Club Moss
Mainanthemum canadense	Wild Lily-of-the-Valley
Myrica gale	Sweet Gale
Oxycoccus microcarpus	Small Cranberry

Petasites palmatus	Coltsfoot
Picea glauca	White Spruce
Picea mariana	Black Spruce
Pinus banksiana	Jackpine
Poa sp.	Meadow grass
Populus balsamifera	Black poplar
Populus tremuloides	Trembling Aspen
Potamogeton sp.	Pondweed
Potentilla tridentata	Three-toothed Cinquefoil
Pteridium aquilinium	Bracken Fern
Ribes sp.	Currant
Rubus chamaemorus	Baked Appleberry
Rubus idaeus	Raspberry
Salix sp.	Willow
Scirpus sp.	Bullrush
Senecio sp.	Groundsel
Solidago sp.	Goldenrod
Sorbus sp.	Mountain Ash
Sphagnum sp.	Sphagnum Moss
Vaccinium uliginosum	Alpine Bilberry
Viburnum trilobum	Highbush Cranberry
Vicia americana	Vetch

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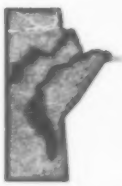


8.0 ADDENDUM – BURNTWOOD RIVER RESERVOIRS

This addendum describes the physical impact on the shorelines and inundated areas of the reservoirs created by the proposed hydro-electric generating stations at the Wuskwatim, Manasan Falls and First Rapids sites on the Burntwood River. Since the Burntwood River will be subjected to the Churchill River Diversion flows for a number of years possibly 10 to 15 years - before the reservoirs are developed, the effect of the reservoirs should be defined as the incremental effect of proceeding from the diversion flow only case to the diversion flow plus reservoir case. While the emphasis in this addendum is on the incremental effect of the reservoirs, some comment on the total effect is included for the sake of clarity.

The reservoirs, for the purposes of this report, have been defined to extend from the dam site upstream to the point, usually at a set of rapids or falls, beyond which the elevation of the normal ice cover under diversion conditions is approximately the same with the dams in place as it is without the dams in place. The reservoir normally increases open water levels for some distance beyond the defined upstream limit of the reservoir. However, in these reaches the unaltered winter levels are higher than the summer levels and determine the upper limit of the effects on vegetation. The incremental effect of the moderately increased summer levels in these reaches is considered to be small in terms of the total effect and is not discussed in this report.

The shoreline, shoreline area and inundated terrain classification systems and the impact process statements presented in the main report also apply to the reservoirs covered by the Addendum.

8.1 RECOMMENDATIONS

The sequence of development of the three generating stations and the proposed forebay levels have been examined with a view to minimizing environmental damage.

The Wuskwatim Reservoir will drown out the rapids on the Burntwood River between Threepoint and Wuskwatim Lakes and thus provide the residents of Nelson House (population 1500) access without portage to Wuskwatim Lake. Footprint, Threepoint and Wapisu Lakes and the river channels joining the lakes are presently travelled extensively by the residents of Nelson House and will likely continue to be used under reservoir conditions. Two forebay elevations have been proposed for Wuskwatim Reservoir - 800 and 810. In terms of inundated useful or potentially useful terrain, such as wildlife habitat, there is very little difference in the two forebay elevations. The majority of the wildlife habitat will have been inundated under the 800 foot forebay conditions. The 810 foot forebay will serve to eliminate the extreme ice jam effect upstream of Gods Rapids. Moreover, the 810 foot forebay will fall within the normal ice cover range. The 810 foot forebay will maintain a constant water level, thereby facilitating shoreline access, and maintenance of real property-docks, etc.

The main advantage in developing the Manasan Falls Reservoir first is that the dam would serve to prevent debris generated in upstream reaches from moving downstream into the Thompson area. Debris in this area could pro-

hibit the use of float planes and make motor boat travel dangerous.

As the Split Lake shorelines will not be greatly affected by the mean open water increment (1.9 feet) under diversion conditions, the shorelines could be kept in a semi-pristine state by constructing the First Rapids Reservoir first. The dam and reservoir would intercept and retain debris generated in upstream reaches and prevent it from entering Split Lake. Additionally, the reservoir would intercept the larger part of that sediment which would otherwise be deposited in Split Lake. The population of the Split Lake community and York Landing community is approximately 800 and 200 respectively.

In summary, there appears to be no great advantage in constructing any one reservoir before the others. However, the total environmental impact would clearly be minimized if all reservoirs were developed as quickly as possible. Available information suggests that the 810 forebay elevation for Wuskwatim is to be preferred over the 800 foot elevation.

8.2 WUSKWATIM RESERVOIR

8.2.1 THE LIMITS OF THE WUSKWATIM RESERVOIR: The Wuskwatim Generating Station is to be located on the Burntwood River at Taskinigup Falls, one mile downstream of the outlet of Wuskwatim Lake and approximately 50 miles downstream from the Notigi Control Structure. Taskinigup Falls is the largest of a series of falls and rapids below the outlet of Wuskwatim Lake.

Two forebay elevations have been proposed - 800 and 810. At both elevations, the reservoir will extend from the dam site at Taskinigup Falls into Wuskwatim Lake and drown out the rapids upstream of Wuskwatim Lake - Early Morning Rapids, Caribou Rapids and Gods Rapids. The winter rise in the level of the normal ice cover will be eliminated from the dam site to the foot of Gods Rapids. The open water levels will be increased over a further length of river through Threepoint (and Footprint) and Wapisu Lakes but will not be increased to the elevation of the normal ice cover over this further length of river. Hence, for the purposes of this report, the Wuskwatim Reservoir is defined to extend from Taskinigup Falls to the foot of Gods Rapids. It is shown on Figure 175.

The levels of Wuskwatim, Threepoint (and Footprint) and Wapisu Lakes under various flow, ice and forebay level conditions are given in Tables 20, 19 and 18 and Figures 93, 94 and 95 of the main report.

8.2.2 EFFECT OF RESERVOIR DEVELOPMENT ON ICE LEVELS: Under diversion only conditions, the normal ice levels are expected to be about 10 feet higher than open water levels from the Notigi to the Wuskwatim site and to produce an ice scoured bank effect similar to that observed on the Lower Churchill and Nelson Rivers. Under reservoir

conditions, the winter ice surcharge and ice scoured bank effect will be eliminated within the defined reservoir.

The possibility of an extreme ice jam effect will be eliminated on Wuskwatim Lake at either forebay level and will be eliminated on Threepoint (and Footprint) and Wapisu Lakes at the 810 forebay level. At a forebay level of 810 the reservoir would in fact extend upstream to Notigi and maintain nearly constant water and ice levels from the Notigi to the Wuskwatim sites.

8.2.3 NATURAL STATE CONDITIONS - WUSKWATIM RESERVOIR SHORELINES: As the brook, river and lake areas of Wuskwatim Reservoir display different characteristics, the natural state conditions will be discussed separately for the three areas: the Burntwood River, Wuskwatim Lake and Wuskwatim Brook.

Mileages of each area are as shown in Table 63.

Burntwood River: In the natural state, the Burntwood River channel consists of long smooth stretches of clay overburden shoreline (Type 23) broken with bedrock headlands (Type 13B) and irregular stretches of bedrock shoreline (Type 14). Types 23, 13B and 14 are represented by 5.8, 4.1 and 5.9 miles of shoreline respectively. While Types 13 and 14 exhibit typical shoreline characteristics, Type 23 is atypical due to the unstable nature of the shoreline materials. Although Type 23 shorelines are not slumping they are active in that shoreline materials are slowly being eroded away. Consequently the trees along the shoreline are slowly falling into the river (Photograph 159). Offshore zones are shallow and often cluttered with undercut trees. In general, Type 23 shorelines are more active along the south shore than the north shore.

A short stretch of granular shoreline (Type 22) exists along the south shore just upstream of the channel widening. Jack Pine forms the dominant treed cover on this granular mineral soil.

The channel widening upstream of Wuskwatim Lake is characterized by the bedrock control shorelines on the south shore (Types 13, 14 and 15) and low alluvial shorelines (Type 24) along the north shore. Broad alluvial zones in this area are the result of decreased velocities and subsequent sedimentation. In general, the tree line along these shorelines marks the upper limit of the water-washed zone while the willow border marks the water-washed zone above the mean water level (Photograph 160). River widenings and tributary mouths contain a wide variety of marsh species. The submerged aquatic plant growth (Potamogeton spp.) is so dense in mid summer that navigation by boat is restricted to a narrow section of the central channel. Circular stands of bulrushes (Scirpus sp.) are located throughout the channel widening while dense extensive stands of water horsetail (Equisetum fluviatile) are restricted to the shallower water offshore of the sedge stands (Carex spp.). Clusters of water lilies (Nuphar sp.) are restricted to the clamer water areas. The best water fowl habitat on the Burntwood River is along these low marsh areas. Type 15 and 24 are represented by 2 and 25 miles of shoreline respectively.

Tributary streams were classified as Type 24. These streams are characterized by their meandering nature and sedge-willow riparian zones. The larger backshore water bodies feeding into the streams were classified as low fen (Type 31) shorelines. Type 31 makes up 5.6 miles of shorelines. Steep bedrock (Type 11) and low willow (Type 28) consist of less than one mile of shoreline each.

Wuskwatim Lake: Wuskwatim Lake is characterized by the occurrence of bedrock shorelines (Type 13B and 15) interspersed with overburden beaches (Type 14). Types 13B, 15 and 14 consist of 19.3, 6.1 and 4.6 miles of shoreline respectively. Type 14 shorelines are characterized by a granular beach and an occassional marsh zone.

The north east section of lakeshore was classified as Type 15 due to the narrow width of the water-washed zone. Types 11, 23 and 24 are restricted in extent making up less than one mile of shoreline each. Type 24 is restricted to tributary areas while active Type 23 is only found in embayments.

Wuskwatim Brook: The area of low relief drained by Wuskwatim Brook is characterized by the high occurrence of Type 24, 28 and 31 shoreline and low occurrence of bedrock shorelines (Type 13 and 14). The 1.3 miles of Type 13 and 14 shorelines are confined to exposed areas of moderate relief. The brook and adjacent areas contain depositional shorelines typical of the channel sections upstream of Wuskwatim as seen in Photograph 160, however, in places organic materials have accumulated to the extent to form low fen (Type 31) shorelines (Photograph 161). In this area, the reduced annual siltation and possible narrower range of water level fluctuations has allowed for the accumulation or organic materials and subsequent formation of fen shorelines. On exposed sites, the water-peat interface is irregular and eroding. These fens are of particular interest due to the patterned distribution of the willows on the peat surface. Herbaceous plants constitute the dominant vegetation as the seasonal surface inundation restricts tree colonization. Dominant vegetation is Carex spp. (Sedges), grasses, feather mosses and shrubs; both Salix sp. (Willows) and members of the Ericaceae (heath) family.

In this area, Type 31 consists of some 17.4 miles of shoreline. The five miles of Type 28 shoreline is restricted to embayments while the majority of the 38.6 miles of Type 24 shoreline is located along the tributaries feeding into Wuskwatim Brook. Less than one mile each, both Types 23 and 25 (slumping overburden shoreline) are located near the mouth of Wuskwatim Brook.

Inundated Terrain: Areas backshore of the land-water interface of both fen and alluvial shorelines are dynamic environments, particularly in the channel area upstream of Wuskwatim Lake. Many of these areas are in the early stages of sedge community development. At one time, the area was treed. Remnant trees in the midst of a bog as seen in the upper right hand corner of Photograph 160 are a clear indication of collapsed forest areas.

The predominant vegetation within the area to be inundated consists of a mosaic of bogs and well drained forested sites (clay hummocks). Many of these clay hummocks are treed with hardwood species, particularly whitebirch. Such sites are characterized by the occurrence of thawing permafrost thereby forming collapse scars. Although these sites do not appear to be actively slumping, they are obviously settled. The more recent scars are characterized by open water and sedges while the maturer sites (as seen in Photograph 162) are characterized by a consolidated sedge matt and woody shrubs.

Treed muskeg is in general confined to valley situations or else on mature collapse scars. Figure 177 and Photograph 166 as shown for Manasan Falls Reservoir are typical of the backshore area of Wuskwatim.

Backshore water bodies and the streams are colonized by a host of marsh species.

8.2.4 POST-DIVERSION PRE-RESERVOIR CONDITIONS - WUSKWATIM RESERVOIR: Under diversion-only conditions, the mean open water level of the defined Wuskwatim Reservoir will be increased by ten feet while the normal ice cover conditions will raise the diversion-only levels an additional nine feet.

Flooding will be contained within the immediate shoreline area of the mildly sloped shorelines whereas it will extend beyond the immediate shoreline area along low alluvial, willow and fen shorelines.

The diversion only shoreline types will not differ substantially from the natural shoreline types, Table 63 and Figure 175.

Shorelines -

Burntwood River: Under normal ice conditions, Type 23 shorelines are expected to develop a scour zone which will be colonized primarily by grasses and sedges. Uprooted trees will likely be evident below the trim line. The tree line as shown in Photograph 159 is not expected to extend down to the mean open water level.

The effect of the ice surcharge action on vegetation is expected to be somewhat similar along the bedrock control shorelines.

The one localized granular shoreline and backshore area will be inundated under open water diversion conditions.

Marsh zones typical of Type 24 and 31 shorelines will be substantially reduced. In general, these shorelines will be set back but not necessarily to the same extent as shown on Figure 175. In certain instances, the organic terrain between the natural and the diversion only contours will form the new shorelines. The majority of the tributary shorelines will rise into a treed clay overburden terrain. As most of these low clay hummocks are permafrosted, the raised water levels will alter the thermal equilibrium of the frozen materials and cause the permafrosted materials to thaw. This accellerated collapsing will result in the horizontal recession of the shoreline.

The one physical structure of significance in this area is an Indian cemetary along the south channel upstream of Wuskwatim Lake Inlet (Photograph 163). Perched on an area of high relief, the cemetary will not be inundated under open water or ice surcharge conditions but may be affected by the erosion of overburden materials.

Wuskwatim Lake: Under open water level diversion only conditions, the bedrock control shorelines will stabilize once the overburden has been eroded from the bedrock to the maximum new water line. As in the natural state conditions, an exposed mineral soil bank will extend from the maximum water line to the uplands. The normal ice cover levels will have the effect of increasing the width of the exposed mineral soil bank. These banks will achieve an atypical appearance due to undercut trees.

The granular beaches typical of Type 14 shorelines will not be re-developed under diversion conditions.

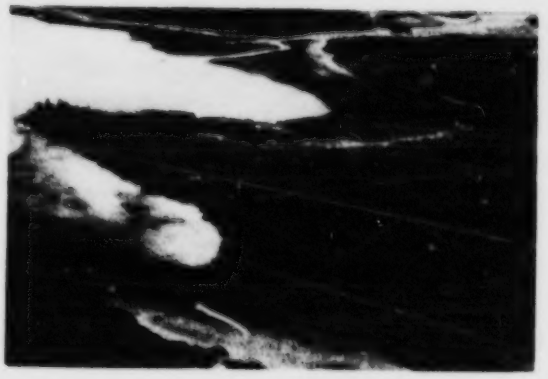
Type 11 shorelines will not be adversely affected by the higher open water and ice cover conditions.

The fish camp base and ice house at the southern portion of the lake will likely be affected by the water level rise and ice surcharge conditions. This peninsula is used each summer as a base camp by the fishermen from Nelson House (Photograph 164). The ten foot rise in levels will convert the peninsula into an island.

Muskwatim Brook: As was the case along the Burntwood River, the marsh zones typical of Type 24 and 31 shorelines will be substantially reduced in width. The new shorelines will generally rise into a treed lacustrine clay terrain and be affected in a manner similar to that discussed for the Burntwood River.

Inundated Terrain: Under open water diversion only conditions, terrain will only be inundated within the channel widenings and tributary areas. In this case, the organic terrain backshore of the low lying shorelines will form portions of the new shoreline. An example of the low organic terrain (sedge communities) expected to rise with the water levels is as shown in Photograph 162.

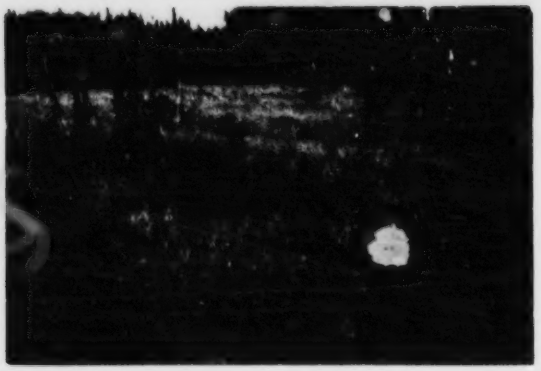
PHOTOGRAPH 159 - An active clay overburden shoreline (Type 23) on the Burntwood River. This is the natural state of a pre-diversion clay shoreline along the Burntwood River. Shoreline access is hampered by the fallen trees and the shallow offshore.



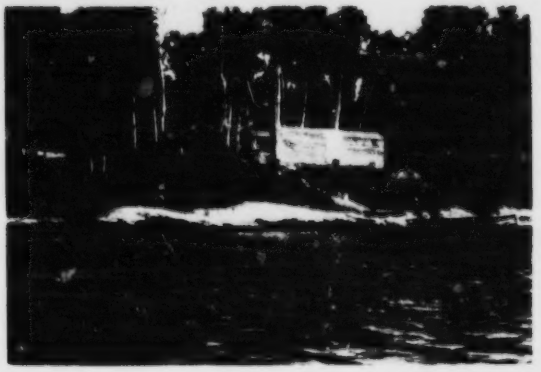
PHOTOGRAPH 160 - Low alluvial shorelines (Type 24) on the Burntwood River upstream of Muskwatim Lake. This channel widening and tributary area is one of the richest marsh zones along the Burntwood River.

PHOTOGRAPH 161 - A fen and alluvial shoreline near the outlet of Wuskwatim Brook.

PHOTOGRAPH 163 - An Indian Cemetary at the inlet of Wuskwatim Lake.



PHOTOGRAPH 162 - A colonized collapse scar in the Burntwood River backshore. Although under post diversion-pre-reservoir conditions the open water level will extend into the treed area, the collapse scar sedge matts will rise with the water levels forming a portion of the new shoreline.



PHOTOGRAPH 164 - A typical bedrock shoreline (Type 13B) on Wuskwatim Lake. Each summer the Nelson House fishermen bring their families to this fishcamp on Wuskwatim Lake. The ice house is replenished with ice each winter.

TABLE 63

WUSKWATIM RESERVOIR

Natural State Shoreline Distances (Miles)

Classification	11	13B	14	15	22	23	24	25	28	31	Total
Burntwood River	.3	4.1	5.9	1.9	.2	5.8	24.9		.4	5.6	49.1
Wuskwatim Lake	.9	19.3	4.6	6.1		.7	.9				32.7
Wuskwatim Brook		.3	1.0			.9	38.6	.2	4.9	17.4	63.1
											144.9

Note: Under post diversion, pre reservoir conditions the total shoreline distance is 162.0 miles

TABLE 64

WUSKWATIM RESERVOIR

Areas of Water Under Natural State Conditions	
Wuskwatim Lake	12,421 acres
Wuskwatim Brook	1,151
Burntwood River	1,603
TOTAL	15,175 acres

Areas of Inundated Terrain Between the Natural State Shoreline and the 800 foot Contour	
Sedge Communities	4,701
Forested Land	31,951
Backshore Water Bodies	1,240
TOTAL	37,892

Note: The area of inundated terrain between the 800 and 810 foot contours is 14,146 acres.

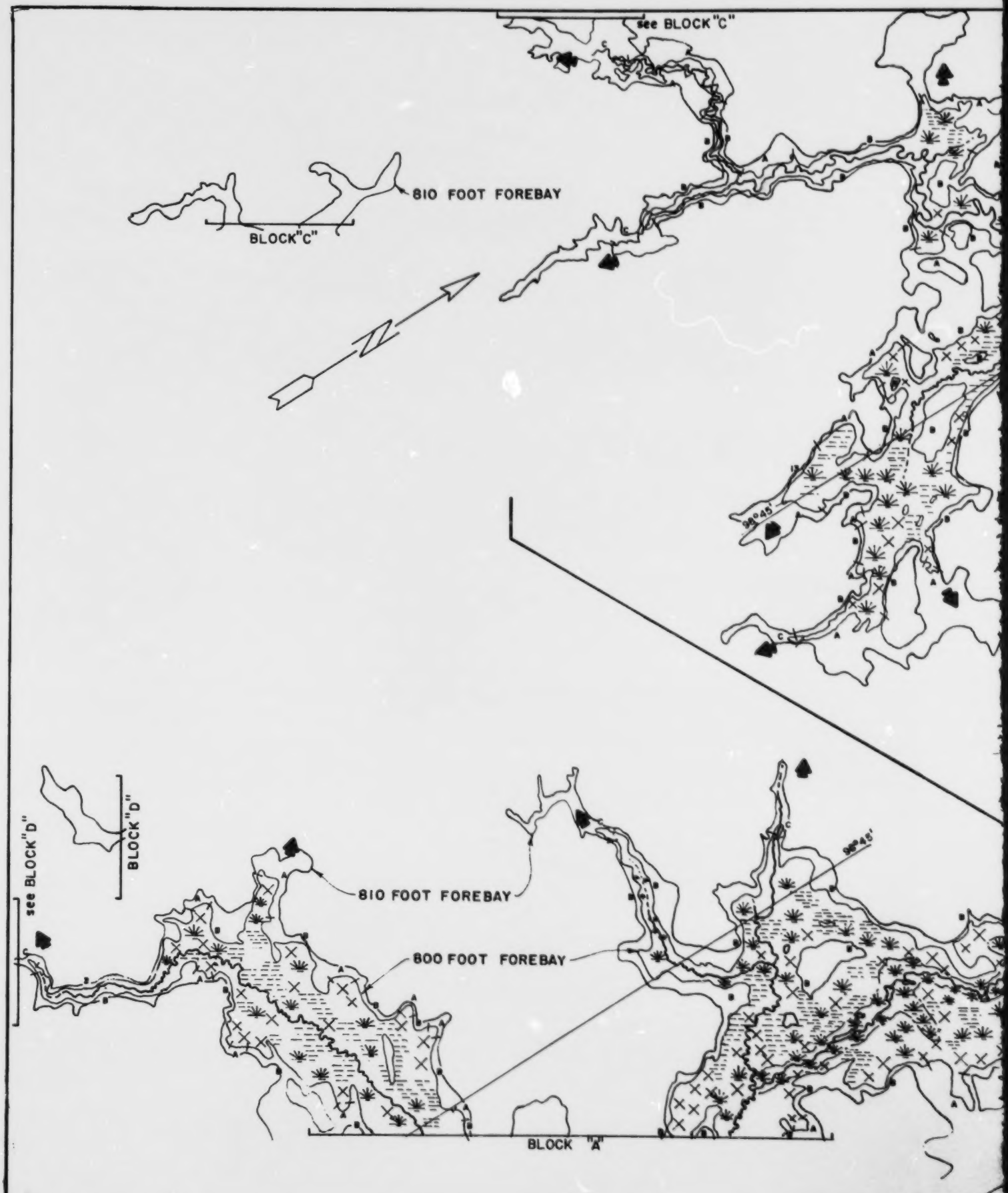
TABLE 65

WUSKWATIM RESERVOIR

Mileage of Shoreline Types for Forebay Elevation of 800 Feet

Classification	11	13B	14	15	22	23	24	25	28	31	A	B	C	Total
Mainland		14.6	13.5			4.6			.5	6.2	50.2	154.6	1.9	246.1
Islands		3.8									.4	64.8		69.0
														315.1

Note: For a forebay elevation of 810 feet the total shoreline distance is 354.0 miles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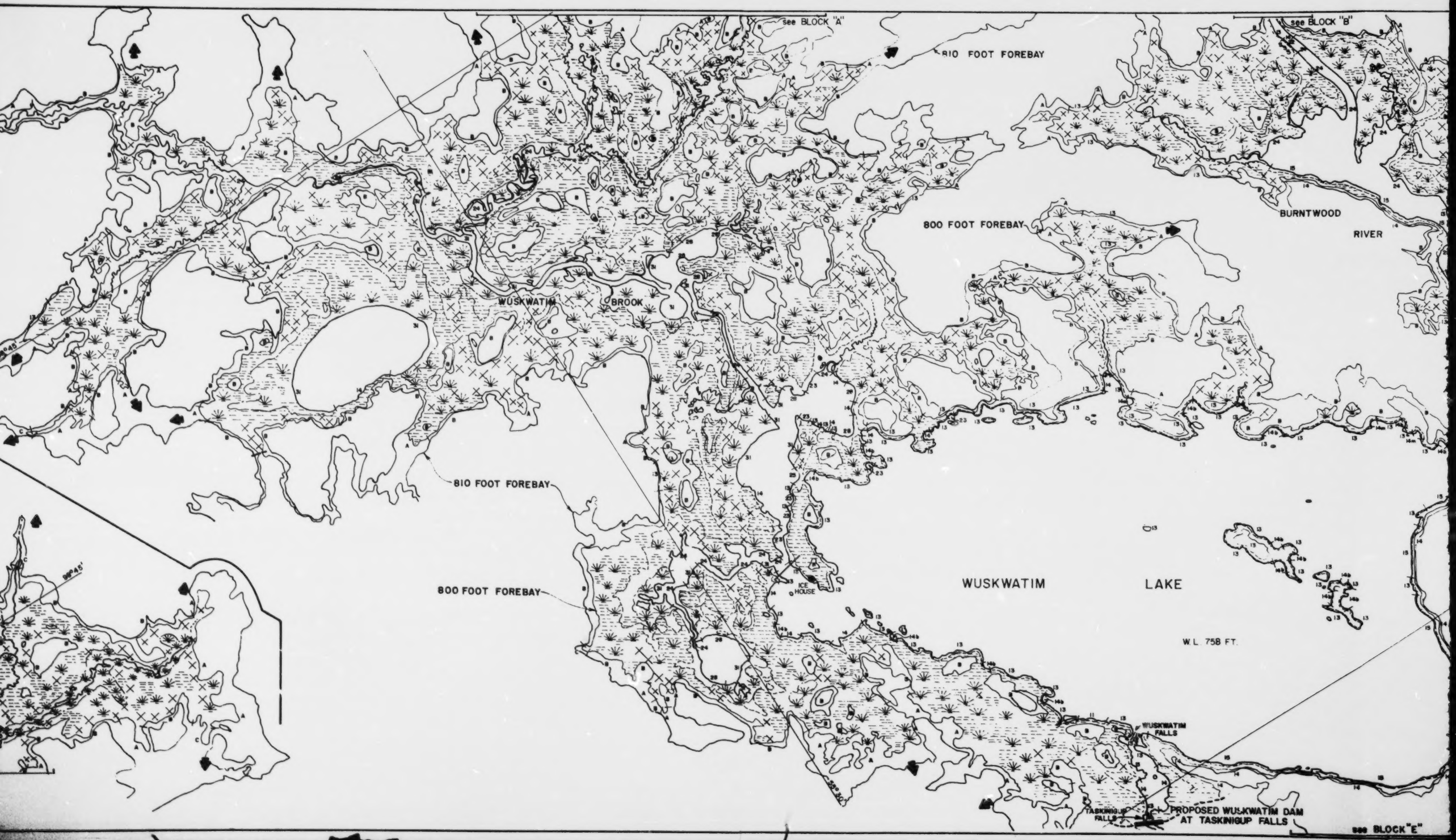
810 FOOT FOREBAY
BLOCK "C"
see BLOCK "D"
BLOCK "D"
810 FOOT FOREBAY
800 FOOT FOREBAY
BLOCK "A"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see BLOCK "B"
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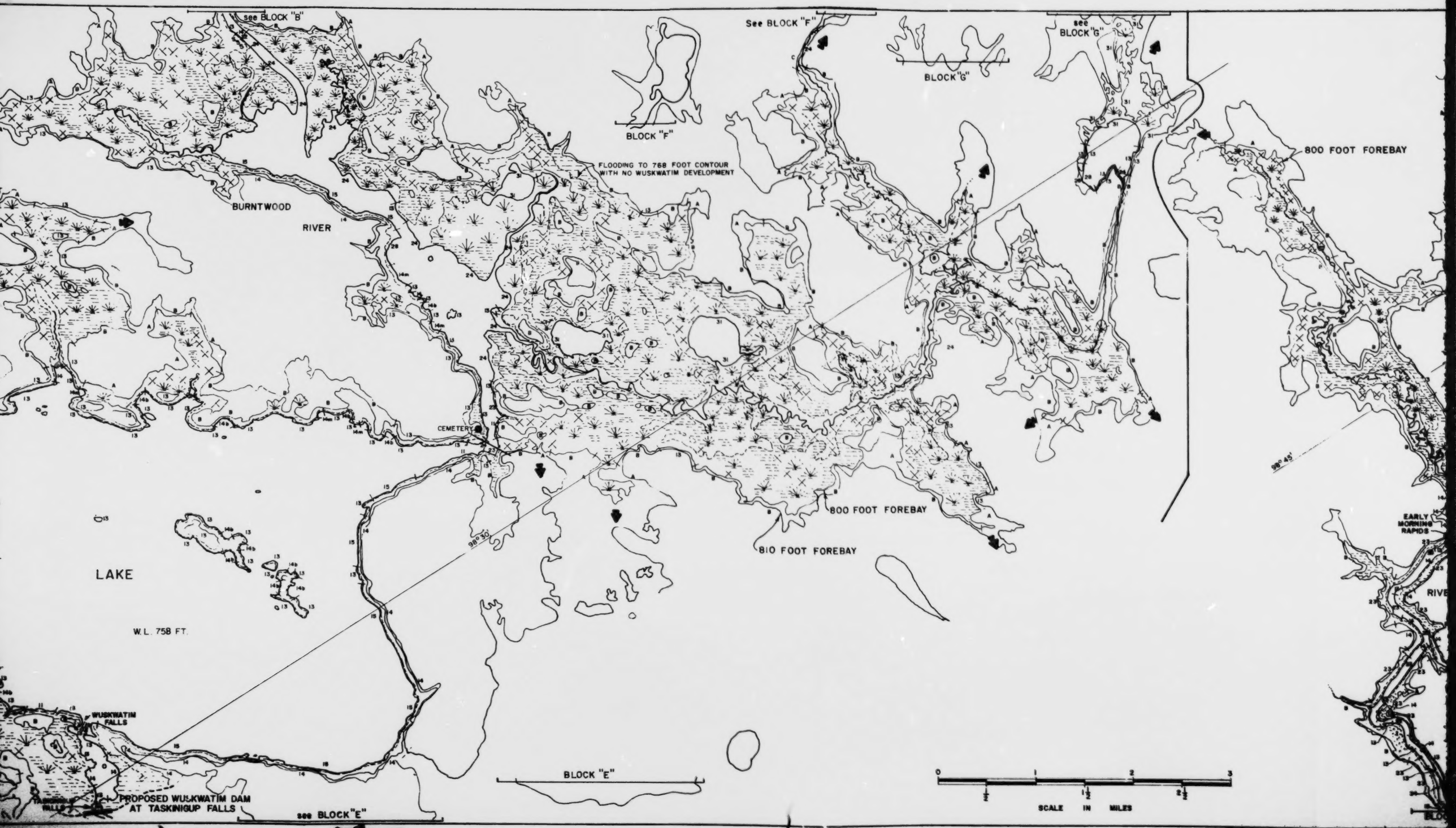
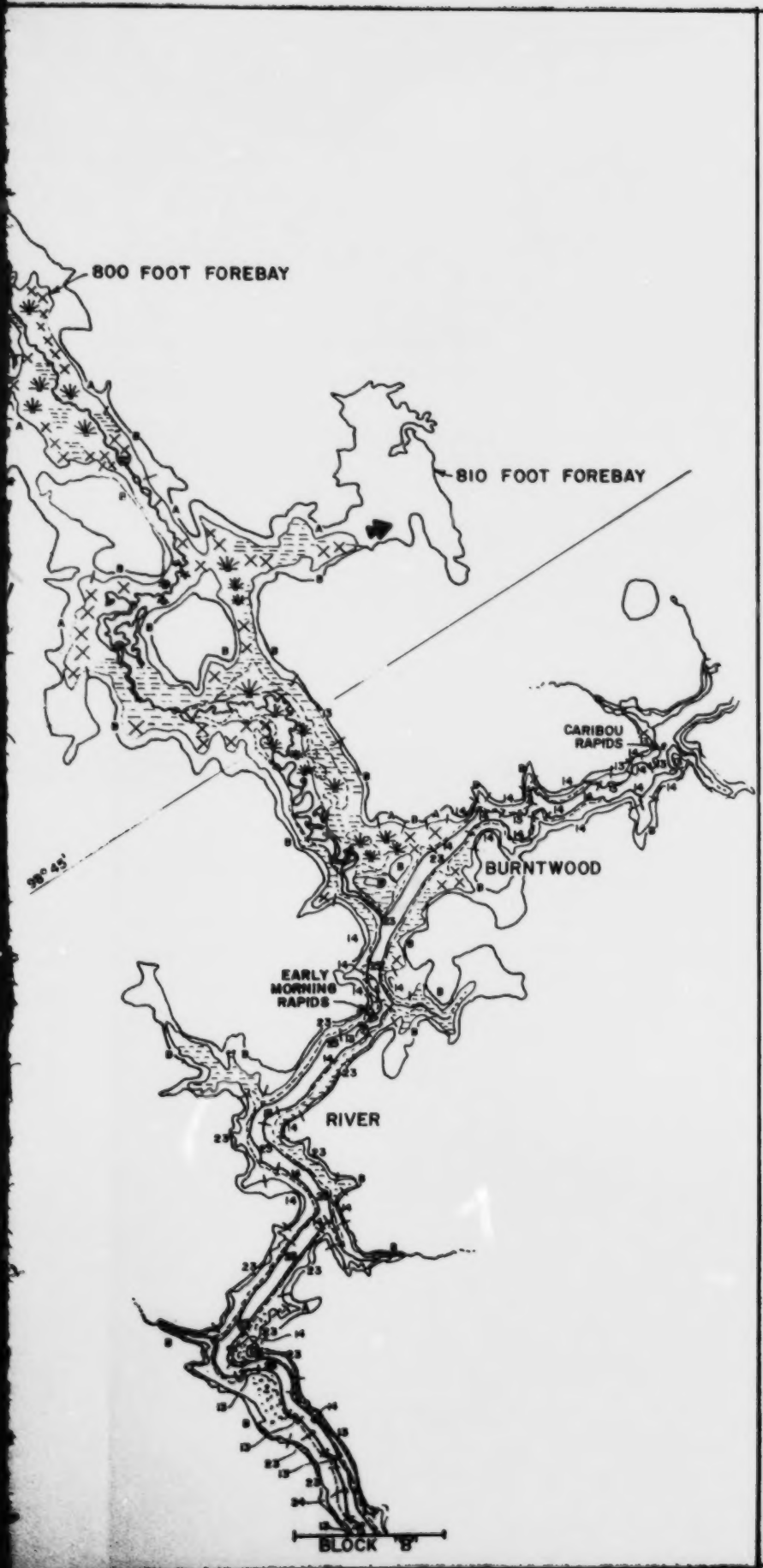
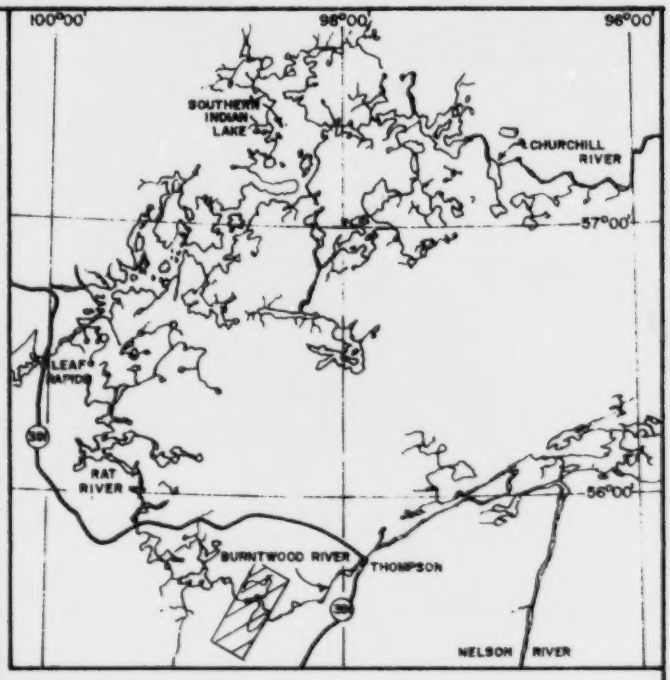
800 FOOT FOREBAY
BURNTWOOD
RIVER
WUSKWATIM
BROOK
810 FOOT FOREBAY
800 FOOT FOREBAY
ICE HOUSE
WUSKWATIM
LAKE
W.L. 758 FT.
WUSKWATIM FALLS
TASKINIGUP FALLS
PROPOSED WUSKWATIM DAM AT TASKINIGUP FALLS
BLOCK "E"


See BLOCK "B"
BLOCK "F"
See BLOCK "F"
BLOCK "G"
see BLOCK "G"
800 FOOT FOREBAY
FLOODING TO 768 FOOT CONTOUR WITH NO WUSKWATIM DEVELOPMENT
BURNTWOOD
RIVER
CEMETERY
LAKE
W.L. 758 FT.
800 FOOT FOREBAY
810 FOOT FOREBAY
EARLY MORNING RAPIDS
WUSKWATIM FALLS
PROPOSED WUSKWATIM DAM AT TASKINIGUP FALLS
BLOCK "E"
See BLOCK "E"
SCALE IN MILES





LOCATION OF MAP

LOCATION PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED
	FLOODING - DIVERSION ONLY
	FLOODING - DAM AND RESERVOIR (PROPOSED)
	DIKES
	OUTLINE OF SEDGE COMMUNITIES

FIG.175

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH
CANADA-MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
BURNTWOOD RIVER
WUSKWATIM RESERVOIR
800 & 810 FOOT FOREBAY
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	RECOMMENDED
T. M.	R. H.	F. P.	

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	JULY/74	1	61-1-1026

8.2.5 IMPACTED RESERVOIR CONDITIONS - WUSKWATIM RESERVOIR: Formation of the Wuskwatim Reservoir at the 800 or 810 foot forebay elevation will substantially alter the character of the area. Inundated terrain and reservoir shorelines at both forebay elevations are as shown in Figure 175 and listed in Tables 64 and 65.

In classifying the reservoir shorelines the natural state shoreline backshore area was used to indicate the type of shoreline expected to evolve along portions of the reservoir. This particularly pertains to areas of moderate and consistant relief where flooding is contained within the immediate backshore of the existing shoreline. Such areas are to be found along the north east portion of Wuskwatim Lake and portions of the Burntwood River. In cases where the flooding extended beyond the natural shoreline backshore into an area where the new shoreline was questionable due to the slope, the materials, the treed cover and the exposure, the shoreline area classificatio system was used. In certain instances, the removed reservoir shoreline will fall onto an exposed rock face, this shoreline therefore has been classified as one of bedrock control.

The reservoir shorelines will be discussed under the following heading, "Future Shorelines".

Future Shorelines: Reservoir shorelines as shown in table 65 have only been classified for the 800 foot reservoir forebay. At the 810 foot forebay, shoreline types will not be substantially altered from those shown in Table 65 although the total shoreline distance will increase. Under the higher elevation particular shorelines will rise from a Type A shoreline area into a Type B shoreline area while others will remain in either a type A or type B shoreline area. In general, the 810 foot forebay will be placed on a better drained terrain than that on the 800 foot forebay.

Reservoir areas predicted to evolve into bedrock control shorelines will achieve stability once the overburden is eroded off the bedrock to the maximum water level. These shorelines will be characterized by the undercut trees. Once stabilized, clay overburden shorelines are expected to appear much as they did under natural state conditions.

The ultimate configuration of Type B shoreline areas, particularily along Wuskwatim Lake is questionable. Exposed shorelines will continue to erode until they stabilize; the majority of these are expected to remain as clay shorelines. Such shorelines will likely be characterized by eroding clay banks and undercut trees. In certain areas, the accumulating debris will form a barrier, thereby breaking wave action and slowing the erosion process. Active slumping can be expected to occur along clay shorelines where flooding has caused permafrosted materials to thaw.

The Type A shoreline areas along the lake proper are not expected to stabilize as soon as the Type B shoreline areas. In this case the low shoreline areas consist of a mosaic of bogs and clay hummocks. Flooding in these areas will likely be greater horizontally than indicated on Figure 175. These shoreline areas will be characterized by flooded trees rather than eroding clay banks. All protected shorelines will remain conjested with standing and fallen trees throughout the reservoir. A greater percentage of fen shorelines (Type 31) will

be created than indicated in Table 65 due to the high occurrence of sedge communities in the backshore areas.

The exposed low lying clay overburden islands will likely erode away. They will appear similar to the anticipated eroding clay islands of Notigi Reservoir.

Under reservoir conditions, the cemetary and the ice house will be inundated.

Inundated Terrain: The total acreage to be inundated under reservoir condition (800 foot forebay) as shown in Table 65 is undoubtably high as a certain percentage of the area will already have been inundated under diversion only conditions (Figure 175). Sedge communities in particular will be reduced. However, the extent of inundation under diversion only conditions is questionable as portions of the sedge communities will rise with the raised water levels. The extent to which these sedge communities will adjust to form portions of the diversion only shoreline is uncertain due to the regulated state of the water levels during the growing season and the winter ice surcharge phenomenon.
Sedge communities that have adjusted to the incremented levels under diversion only conditions are expected to rise with the reservoir levels (800 and 810 forebay). Those forming a consolidated peat matt will exhibit a degree of resiliency while those rooted into the alluvium will be flooded. Upon inundation, hundreds of small sedge communities (bogs and floating fens) will rise with the water levels. Those in the extremities of the reservoir will be contained by the inundated standing trees while those adjacent to the lake and channel will be free floating. A small percentage of these sedge communities will form a fen shoreline at the new shoreline.

The extent of flooded standing trees will be greatest in the tributary areas of the reservoir. However, the total forested terrain acreage to be inundated is not as high as that shown in Table 64 due to the hundreds of collapse scars located throughout the treed areas.

8.2.6 SUMMARY STATEMENT - WUSKWATIM RESERVOIR: For the purpose of this report, Wuskwatim Reservoir extends from the dam site at Taskinigup Falls upstream through Wuskwatim Lake to Gods Rapids on the Burntwood River. It is at this point that the water levels under ice cover diversion only conditions are similar to those of the backed up reservoir water levels. Formation of the reservoir at the 800 foot forebay will flood out Early Morning, Caribou and Gods Rapids, and raise the water levels 32 feet (768 to 800) at Wuskwatim Lake, 18 feet (782 to 800) between Early Morning and Caribou Rapids and back the water up over Gods Rapids into Threepoint, Footprint and Wapisu Lakes. Under normal open water conditions (33,400 cfs) Threepoint and Footprint Lake will rise by four feet (800 to 804) and Wapisu Lake will rise by three feet (802 to 805). Forebay development at the 810 foot contour will raise the levels an additional ten feet on Wuskwatim, seven feet on Wapisu and eight feet on Threepoint and Footprint.

Reservoir development will eliminate the nine foot rise in levels (768 to 777) anticipated to occur in the Burntwood River at Wuskwatim Lake under post diversion-pre reservoir, normal ice cover conditions. Winter ice levels of Wapisu, Threepoint and Footprint Lake will still rise an additional eight feet under reservoir conditions (800 foot forebay). However, reservoir development at the 810 foot elevation will totally eliminate the effects of the winter ice surcharge at Wapisu, Threepoint and Footprint Lakes. At the 810 foot forebay, the

water levels will be constant between Wuskwatim to Wapisu Lakes.

In the natural state the Burntwood River channel consists of alternating stretches of clay and bedrock shorelines while the channel widenings, tributary streams and brooks of the Burntwood River and Wuskwatim Lake support wide expanses of lush marsh. These wetlands are the richest marshes along the diversion route and support a variety of wildlife species. Wuskwatim Lake is characterized by long irregular stretches of bedrock shorelines interspersed with sand beaches.

Under post diversion-pre reservoir conditions, the majority of shorelines will be characterized by an ice scour zone and subsequent herbaceous vegetation above the mean open water level while the marsh zone typical of the natural state conditions will be substantially reduced. Low lying organic terrain (bogs and fens) between the 758 and 768 foot contour is expected to form portions of the diversion only shoreline. Under diversion only conditions, the area between Taskinigup Falls and Caribou Falls consists of 164 miles of impacted shoreline. In comparison the natural waterway consists of 145 miles of shoreline.

At the 800 foot forebay, Wuskwatim Reservoir is 53,067 acres in size and contains 315 miles of shoreline while at the 810 foot forebay, the reservoir is 67,213 acres in size and contains 354 miles of shoreline. Formation of the reservoir (800 foot forebay) will inundate 15,175 acres of natural river and lake surface, 4,701 acres of wetland type communities (bogs and fens), 31,951 acres of forested land and 1,240 acres of backshore water bodies. The 14,146 acres between the 800 and 810 foot forebay is mostly treed.

Shorelines that are contained within the backshore area of the natural shoreline will stabilize the soonest. Bedrock shorelines will be achieved once the overburden is eroded while the clay overburden shorelines along the channel will appear much as they did in the natural state.

The majority of the shorelines will extend beyond the natural shoreline backshore area. Exposed shorelines will continually erode until they stabilize. Active slumping will occur along the clay shorelines where flooding has cause permafrosted materials to thaw. Protected shorelines will remain congested with standing and fallen trees while inundated bogs and fens in the reservoir extremities will form portions of the new shoreline.

Low lying clay overburden islands exposed to wave action will erode away. The Indian cemetary at the inlet of Wuskwatim Lake and the ice house at the mouth of Wuskwatim Brook will be inundated.

8.3 MANASAN FALLS RESERVOIR

8.3.1 THE LIMITS OF MANASAN FALLS RESERVOIR:

The Manasan Falls Generating Station is to be located on the Burntwood River at Manasan Falls just upstream of the junction of the Manasan and Burntwood Rivers five miles south west of Thompson, Manitoba.

At the proposed 690 foot forebay elevation the reservoir will extend from the dam site at Manasan Falls into Birch Tree Lake and drown out Kepuche Falls, Kepuche Rapids and Jackpine Falls.

Under reservoir conditions the rise in the level of the normal ice cover will be eliminated to Jackpine Falls. The open water levels will be increased over a further length of river through Opagano Lake but will not be increased to the elevation of the normal ice cover over this further length of river. Hence, for the purposes of this report, the Manasan Falls Reservoir is defined to extend from Manasan Falls to the foot of Jackpine Falls. The reservoir is as shown in Figure 176.

The levels of Opagano and Birch Tree Lake and the Burntwood River under various flow, ice and forebay level conditions are given in Tables 22 and 23 and Figures 97 and 98.

8.3.2 EFFECTS OF RESERVOIR DEVELOPMENT ON ICE LEVELS:

Under diversion only conditions, the normal ice levels are expected to be about 10 feet higher than open water levels from Wuskwatim Lake to the Manasan Falls site and to produce an ice scoured bank effect similar to that observed on the Lower Churchill and Nelson Rivers. Under reservoir conditions, the winter ice surcharge and subsequently ice scoured bank effect will be eliminated within the defined reservoir.

The possibility of an extreme ice jam will be eliminated within the defined reservoir.

8.3.3 NATURAL STATE CONDITIONS - MANASAN FALLS RESERVOIR:

Shorelines: As Wapishtigau and Birch Tree Brook display different characteristics from that of the Burntwood River and Birch Tree Lake, each area will be discussed separately. The natural shoreline mileages of each area are as shown in Table 66.

Burntwood River and Birch Tree Lake: The river and lake shores are characterized by the alternating series of bedrock (Type 13 and 14) and clay overburden (Type 23 and 25) shorelines. The majority of Type 23 shorelines as shown in Photograph 159 are active. In general, the Type 23 shorelines are more active on the south rather than the north shore. In the past the trend seems to have been to classify the Type 23 shorelines in this area as slumping clay overburden shorelines (Type 25). This, however, is a misinterpretation of the actual shoreline instability. Along the channel, headlands are invariably Type 13B while embayments are either Type 23 or 14. Type 15 shorelines are infrequent along the channel but common to Birch Tree Lake.

Birch Tree Lake is simply a widening of the Burntwood River. In the natural state, the lake is less than twelve feet deep. Backshore areas are characterized by the thick slumping lacustrine clay deposits (Photograph 165). Shoreline recession has only been halted at headlands due to the bedrock control (Type 13B). However, even these backshore areas are unstable due to the depth of backshore overburden. Types 13B, 14, 23 and 25 consist of 7.5, 11.1, 13.7 and 5.1 miles of shoreline respectively. The 3.3 miles of low alluvial shoreline (Type 24) are restricted to silt bars

along shorelines and tributary streams. These sites of deposition are usually colonized by sedges (Carex spp.) and willows (Salix sp.) in the water-washed zone. The silt bars of stable Type 23 shorelines, Type 24 shorelines and Type 14 embayments are not as extensive as those upstream of Wuskwatim Lake. Submerged aquatic plants were only evident in Birch Tree Lake.

Steep bedrock shorelines (Type 11) and low willow shorelines (Type 28) make up less than one mile of shorelines each.

The one physical structure recognized in the area is an active Trappers Cabin across from the mouth of Wapishtigau Brook.

Wapishtigau Brook: Wapishtigau brook is characterized by the meandering Type 24 shorelines. Alluvium is colonized with horsetails (Equisetum fluviate) leaving only a narrow meandering channel to navigate while the water-washed zone supports sedges (Carex spp.) and willows (Salix sp.). The east fork of the brook is fed by a lake characterized by Type 28 and 31 shorelines. Type 24, 28 and 31 consists of 7.7, 9.1 and 1.9 miles of shoreline respectively.

Birch Tree Brook: The north-east portion of Birch Tree Brook was classified as a Type 28 shoreline (14.8 miles). Alluvium along the brook is colonized by a variety of emergent and submerged aquatic plants and willows. The river mouth and brookshores are similar to those shown in Photograph 160.

The remaining 42.6 miles of shoreline, classified as Type 23, changes character as it turns and heads south-west. Upstream stretches of channel tortuously meander through lacustrine clay deposits (Figure 177). The shifting brook actively erodes the outside of the meander depositing the silt on the inside of the bend. Old channel meanderings, now oxbow lakes are colonized by a variety of marsh species. The accumulating silt bars are colonzied by sedges and willows.

Inundated Terrain: The low terrain adjacent to Birch Tree Brook is similar to that described for the backshore area of alluvial shorelines in Wuskwatim Reservoir. However, the few collapse areas inspected along Birch Tree were larger than those observed at Wuskwatim. In this case the consolidated quaking sedge matts were in the early stages of shrub colonization. Further upstream the collapse scars are smaller (Figure 177). The successional state of the sedge communities in the upland areas varies as seen in Photographs 165 and 166. Well established, the backshore bog in Photograph 165 is colonized by black spruce. Active collapsing is evident along the tree line adjacent to the water surface. Successional rates may not proceed as fast in the floating fen area as shown in Photograph 166 where the flowing water is condusive to the perpetuation of the sedge matt sere.

In this reservoir the inundated forested land consists of treed clay overburden, treed muskeg and treed muskeg interspersed with collapse scars. This backshore area is one of the most complex and diverse environments along the diversion route; permafrosted overburden is thawing to create collapse scars, low lying clay overburden is impeding drainage thereby creating thousands of pot holes (bogs) and supporting treed muskeg while the meandering streams are creating oxbow lakes and depositing silt to form marsh zones. The variety of treed cover as

shown in Figure 177 and Photographs 165 and 166 is largely a function of the restricted drainage.

In general the well drained clay overburden sites support a variety of trees while the treed muskeg is restricted to valley areas lying between the clay overburden at a higher elevation and sedge communities at a lower elevation. The treed muskeg distribution is almost sinuous in form.

8.3.4 POST-DIVERSION - PRE RESERVOIR CONDITIONS - MANASAN FALLS RESERVOIR: Under post diversion - pre reservoir conditions the mean open water levels of Manasan Falls Reservoir will be increased by approximately nine feet while normal ice cover conditions will raise the diversion only levels an additional eight feet.

Flooding will be contained within the immediate shoreline area of the lake and channel whereas it will extend beyond the natural shoreline area in the tributary areas.

The diversion only shoreline (636.5 foot contour) as shown in Figure 176 and listed in Table 66 was not classified as per shoreline type as these shoreline types will not vary significantly from the natural state shoreline types. The diversion only shoreline distances are less than the natural state shoreline distances as the raised water levels will not influence the tributary areas that lie at a higher elevation, above the maximum flood levels.

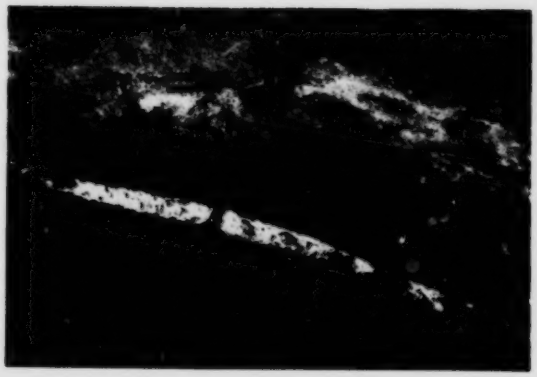
Shorelines - Burntwood River and Birch Tree Lake: The effect of the ice surcharge will be particularily evident along the shorelines exhibiting a lacustrine clay backshore overburden. Moderately sloped clay bank shorelines may erode to the extent that they will develop into slumping overburden shorelines. Bedrock control lakeshores exhibiting a high clay bank will likely also develop into slumping clay shorelines. The natural and newly created slumping shorelines will have achieved a natural appearances by the time the reservoir is formed.

The silt bars and submergent aquatic vegetation typical of the natural state shorelines will not be redeveloped to the same extent under diversion only conditions.

The trapper's cabin will be inundated under open water diversion only conditions.

Wapishtigau Brook - Birch Tree Brook: The marsh zones typical of both brook areas will be reduced in extent. The new shoreline will generally rise into a treed lacustrine clay area. As most of these low clay hummocks are permafrosted the raised water levels will alter the thermal equilibrium of the frozen materials hence causing the permafrosted materials to thaw. This accellerated collapsing will result in the horizontal recession of the shoreline.

Inundated Terrain: Under open water diversion only conditions, Terrain will only be inundated within the brook areas. The organic terrain between the natural and diversion only contours will form portions of the new shoreline. The Birch Tree Brook area will contain a greater amount of inundated trees than the Wapishtigau Brook area.



PHOTOGRAPH 165 - A slumping clay overburden shoreline (Type 25) on Birch Tree Lake.

PHOTOGRAPH 166 - A floating sedge community in the upland area backshore of Birch Tree Lake.

TABLE 66

MANASAN FALLS RESERVOIR

Mileages of Shoreline Types under Natural State Conditions

Classification	11	13B	14	23	24	25	28	31	Total
Burntwood River & Birch Tree Lake	.1	7.5	11.1	13.7	3.3	5.1	.3		41.1
Wapishtigau Brook					7.7		2.1	1.9	11.7
Birch Tree Brook				42.6			14.8		57.4
									110.2

Note: Under post diversion, pre reservoir conditions the total shoreline distance is 79.0 miles.

TABLE 67

MANASAN FALLS RESERVOIR

Area of Water Under Natural State Conditions is 3,630 acres

Area of Inundated Terrain between the Natural Shoreline and the 690 Foot Contour

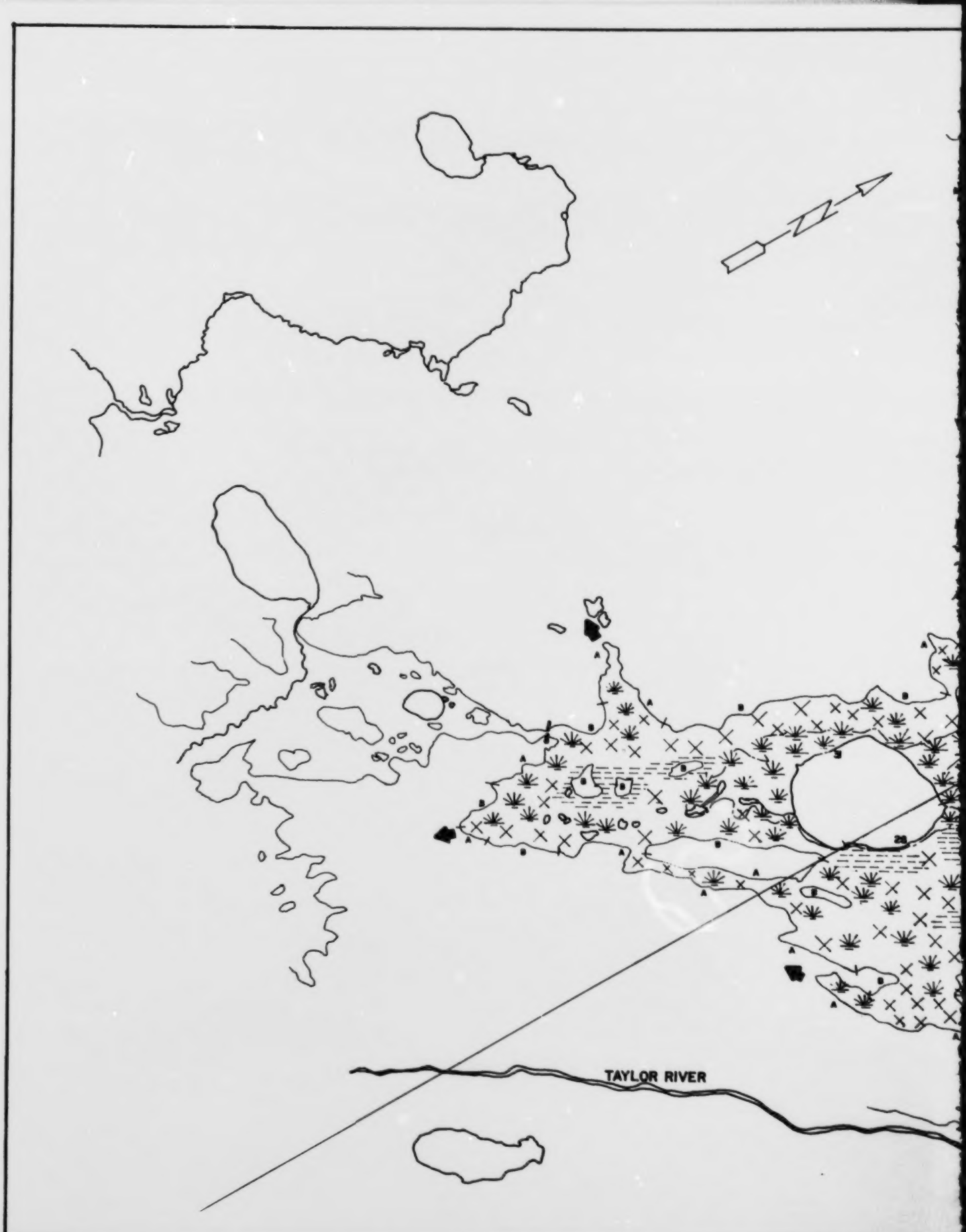
Sedge Communities	2,349 acres
Forested Land	34,199
Backshore Water Bodies	785
TOTAL	37,333 acres

TABLE 68

MANASAN FALLS RESERVOIR

Mileage of Shoreline Types for a Forebay Elevation of 690 Feet

Classification	11	13B	14	23	24	25	28	31	A	B	C	Total
Mainland	11.4	.8	7.4	.3					51.9	108.5	1.6	181.9
Islands	.5								3.7	54.9		59.1
												241.0


TAYLOR RIVER

BIRCH TREE BROOK

BLOCK "A"

JACKPINE FALLS

BURNTWOOD RIVER

UPPER KEPUCHE RAPIDS

KEPUCHE FALLS

CABIN

FLOODING TO 690 FOOT CONTOUR WITH MANASAN DEVELOPMENT

WAPISHTIGAU BROOK

BIRCH TREE LAKE

W.L. 628 FT.

MANASAN RIVER

OSPWAGAN LAKE

BLOCK "A"

TRANSMISSION LINE

BLOCK "A"

RR 281

98°00'

OOT CONTOUR
ELOPMENT

BIRCH TREE LAKE

W.L. 628 FT.

FLOODING TO 640 FOOT CONTOUR
WITH NO MANASAN DEVELOPMENT

BIRCH TREE BROOK

PROPOSED DAM SITE
AT MANASAN FALLS

BURNTWOOD RIVER

0 1 2 3
½ 1½ 2½
SCALE IN MILES

100°00'

SOUTHERN INDIAN LAKE

LEAF RAPIDS

RAT RIVER

BURNTWOOD RIVER

LOCATION OF MAP

LOCATION

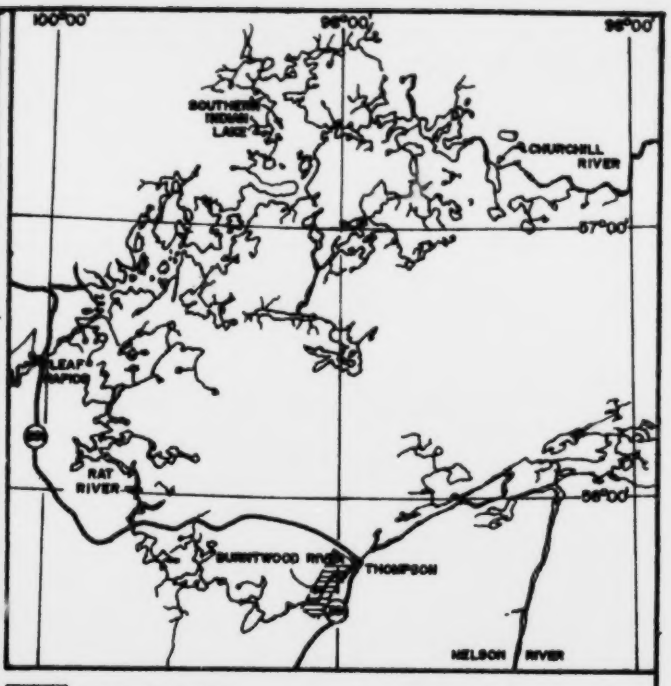
LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIE
	TREED MUSKEG TE
	TREED MUSKEG TE
	GLACIAL DRIFT TE
	BEDROCK OUTCROP
	CLAY OVERBURDEN
	FLOODING POSSIBLY
	FLOODING - DIVER
	FLOODING - DAM A
	DIKES
	OUTLINE OF SEDGE

PROVINCE OF MANI
DEPARTMENT OF MINES, RESOURCES AND
WATER RESOURCES B
CANADA - MANITOB
LAKE WINNIPEG, CHANNEL AND SELKI

PHYSICAL IMPACT O
BURNTWOOD R
MANASAN FALLS
640 FOOT FL
CHANNELS AND RESERVOIR AREA

T. M.	R. H.	F. P.
AS SHOWN	JULY/74	2



LOCATION OF MAP

LOCATION PLAN

SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED
	FLOODING - DIVERSION ONLY
	FLOODING - DAM AND RESERVOIR (PROPOSED)
	DIKES
	OUTLINE OF SEDGE COMMUNITIES

FIG. 176

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH
CANADA-MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
BURNTWOOD RIVER
MANASAN FALLS RESERVOIR
690 FOOT FOREBAY
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	SUPERVISED
T. M.	R. H.	F. P.	

SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	JULY/74	2	61-1-1026

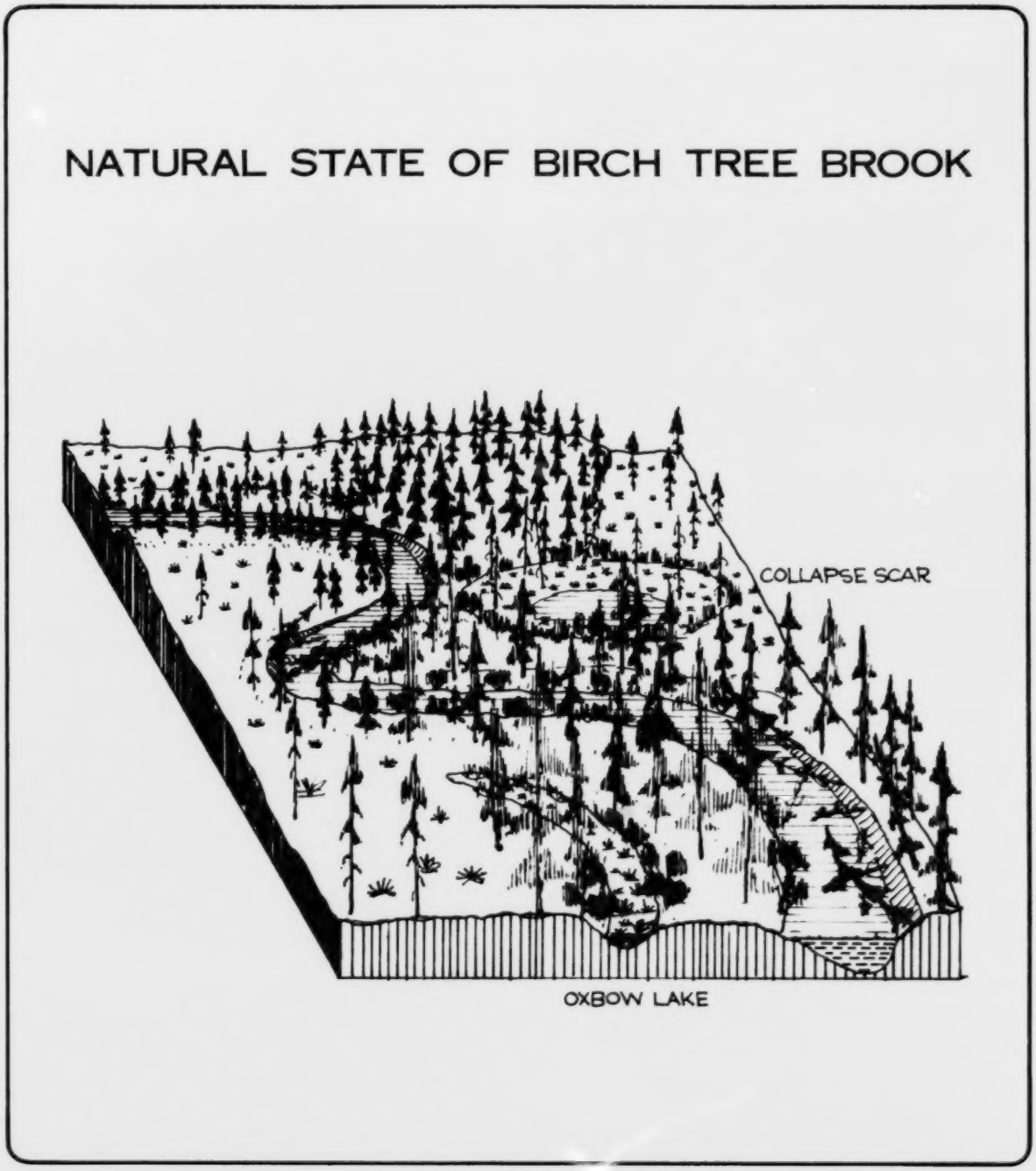


FIGURE 177

8.3.5 IMPACTED STATE CONDITIONS - MANASAN FALLS RESERVOIR: Formation of Manasan Falls Reservoir at the 690 foot forebay elevation will substantially alter the character of the area. The reservoir shoreline and inundated terrain is as shown in Figure 176 and listed in Tables 67 and 68.

In classifying the reservoir shorelines, the natural state shoreline backshore area was used to indicate the type of shoreline expected to evolve along the upper channel portions of the reservoir. The shoreline area classification system was used throughout the remainder of the reservoir where flooding extended beyond the immediate backshore of the existing shoreline. In this case, the ultimate state of the shoreline is questionable due to the slope, the materials, the treed cover and the exposure. In certain instances, the reservoir shoreline would fall onto an exposed rock face. This shoreline, therefore, would have been classified as one of bedrock control.

The reservoir shorelines will be discussed under the following heading "Future Shorelines".

Future Shorelines: The channel shorelines in the upper portion of the reservoir are expected to stabilize the soonest (Types 13, 14 and 23). Shorelines classified as Type 11 fall within a bedrock outcrop, hence they are in a stable state. The majority of the remaining shorelines fall within Type A and Type B shoreline areas. These will likely evolve into Type 23 or Type 25 shorelines. Active slumping can be expected to occur along the clay shorelines where flooding will result in thawing of permafrosted materials. Although initially the erosion will be greater, shorelines backshore of the Burntwood River and Birch Tree Lake are expected to achieve stability before those backshore of Wapishtigau and Birch Tree Brook. All protected shorelines will remain conjested with standing and fallen trees throughout the reservoir.

The majority of the newly created low clay islands will erode away unless bedrock control is achieved.

At the 690 foot forebay elevation, the headpond will flood portions of the transmission line and PR 391 extending from Thompson to Nelson House. This flooding in the northern extremity of the reservoir will necessitate the relocation of the line and the highway.

Inundated Terrain: The inundated acreage as shown in Table 67 is undoubtably high as a certain percentage of the area will already have been inundated under diversion only conditions (Figure 176). This will particularly influence the sedge community acreage. Sedge communities that have risen with the diversion only water levels will also rise with the reservoir levels. The majority of Sedge communities (collapse scars) that lie between the diversion only and reservoir forebay contours will rise with the reservoir levels.

Sedge communities impacted in the brook areas will be contained by the inundated standing trees while those near open bodies of water will be free floating. A small percentage of the impacted sedge communities will be instrumental in forming fen shorelines.

The extent of flooded standing trees will be greatest in the tributary areas of the reservoir. Although the inundated terrain in Manasan Falls Reservoir is similar to that of Wuskwatim Reservoir, Manasan Falls contains a larger proportion of treed terrain. In general, collapse scars are less frequent.

8.3.6 SUMMARY STATEMENT - MANASAN FALLS RESERVOIR: For the purpose of this report, Manasan Falls Reservoir extends from the dam site at Manasan Falls upstream through Birch Tree Lake to Jackpine Falls on the Burntwood River, a distance of approximately 17 miles. It is at this point that the water levels under ice cover diversion conditions are similar to those of the backed up reservoir levels. Formation of reservoir at the 690 foot contour will inundate Kepuche Falls, Kepuche Rapids and Jackpine Falls, raise the water levels 54 feet (636 to 690) at Birch Tree Lake, 32 feet (658 to 690) between Kepuche Falls and Kepuche Rapids and 26 feet (664 to 690) between Kepuche Rapids and Jackpine Falls and back the water up over Jackpine Falls into Opegano Lake. Under normal open water diversion conditions (33,700 cfs) Opegano Lake will rise five feet (685 to 690).

Reservoir development will eliminate the eight foot rise in levels (636 to 644) anticipated to occur at Birch Tree Lake under post diversion-pre reservoir, normal ice cover conditions. However, Opegano Lake will rise an additional four feet (690 to 694) under reservoir conditions.

In the natural state the Burntwood River consists of alternating stretches of bedrock and unstable clay shorelines while Birch Tree Lake consists of slumping clay banks and bedrock headlands. Wapishtigau and Birch Tree Brook shorelines are bordered by wide marsh zones.

Under post diversion-pre reservoir conditions, the mildly sloped clay overburden banks will be characterized by an ice scour zone and subsequent herbaceous vegetation zone above the mean open water level. A greater percentage of the shoreline area will consist of slumping clay banks while the occurrence of bedrock control shorelines will be reduced. Marsh zones typical of the brook areas will be substantially reduced. The low lying organic terrain (bogs and fens) between the natural and diversion only shorelines in the Birch Tree Brook vicinity is expected to form portions of the diversion shoreline. Under diversion only conditions the area between Manasan and Jackpine Falls will consist of 79 miles of impacted shoreline while the natural conditions waterway consists of 110 miles of shoreline.

At the 690 foot forebay, Manasan Falls Reservoir is 40,953 acres in size and contains 241 miles of shoreline. Of the inundated terrain, 3,630 acres consist of natural river and lake surface, 2,349 acres of wet land type communities (bogs and fens) 34,199 acres of forested land and 785 acres of backshore water bodies.

Shorelines that are contained within the backshore area of the natural shoreline will stabilize the soonest. Bedrock shorelines will be achieved once the overburden is eroded while the clay overburden shorelines along the channel will appear much as they did in the natural state. Exposed shorelines will continually erode until they stabilize. Active slumping will occur along the clay shorelines where flooding has caused permafrosted materials to thaw. Protected shorelines will remain congested with standing and fallen trees while inundated bogs and fens in the reservoir extremities will form portions of the new shoreline.

Low lying clay overburden islands exposed to wave action will erode away.

At the 690 foot forebay elevation portions of PR 391 and the transmission line extending from Thompson to Nelson House will be flooded.

8.4 FIRST RAPIDS RESERVOIR

8.4.1 THE LIMITS OF FIRST RAPIDS RESERVOIR:

The First Rapids Generating Station is to be located on the Burntwood River approximately 40 miles downstream of Thompson.

At the 610 foot forebay elevation, the reservoir will extend from the dam site at First Rapids upstream to Third Rapids, a distance of approximately 16 miles. The winter rise in the level of the normal ice cover will be eliminated to the foot of Third Rapids. Open water levels upstream of Third Rapids will not be substantially effected. Moreover, the normal ice cover level will be higher than the open water levels. Hence for the purposes of this report First Rapids Reservoir is defined to extend from First Rapids to Third Rapids. The area is as shown in Figure 178.

The water level between Apusigamasi Lake and First Rapids under various flow, ice and forebay level conditions are given in Tables 25 and 26 and Figures 100 and 101.

8.4.2 EFFECTS OF RESERVOIR DEVELOPMENT ON ICE LEVELS:

Under diversion only conditions, the normal ice levels are expected to be about 10 feet higher than the open water levels from Manasan Falls to First Rapids and to produce an ice scoured bank effect similar to that observed on the Lower Churchill and Nelson Rivers. Under reservoir conditions, the winter ice surcharge and subsequent ice scoured bank will be eliminated within the defined reservoir.

The possibility of an extreme ice jam will also be eliminated within the defined Reservoir.

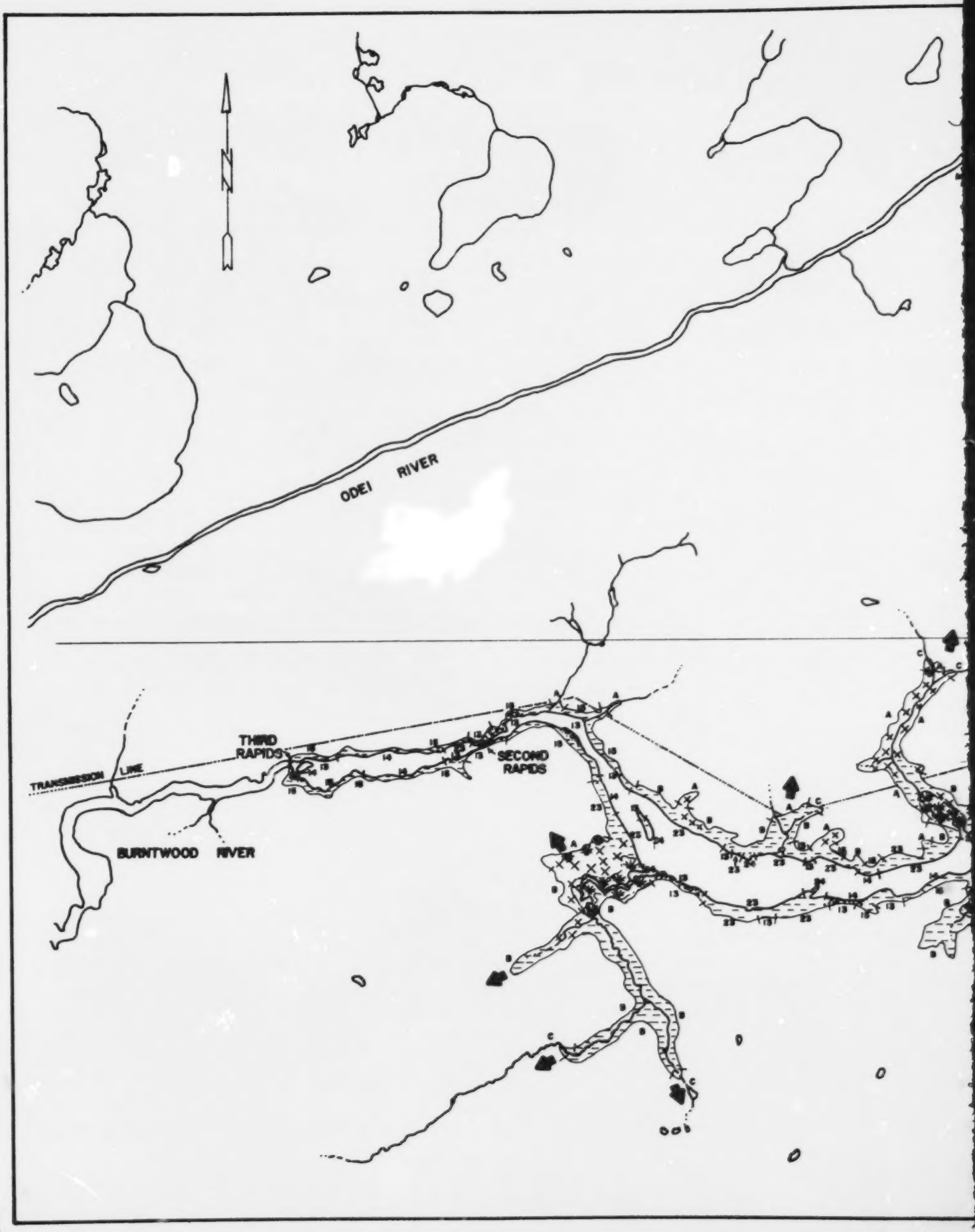
8.4.3 NATURAL STATE CONDITIONS - FIRST RAPIDS RESERVOIR:

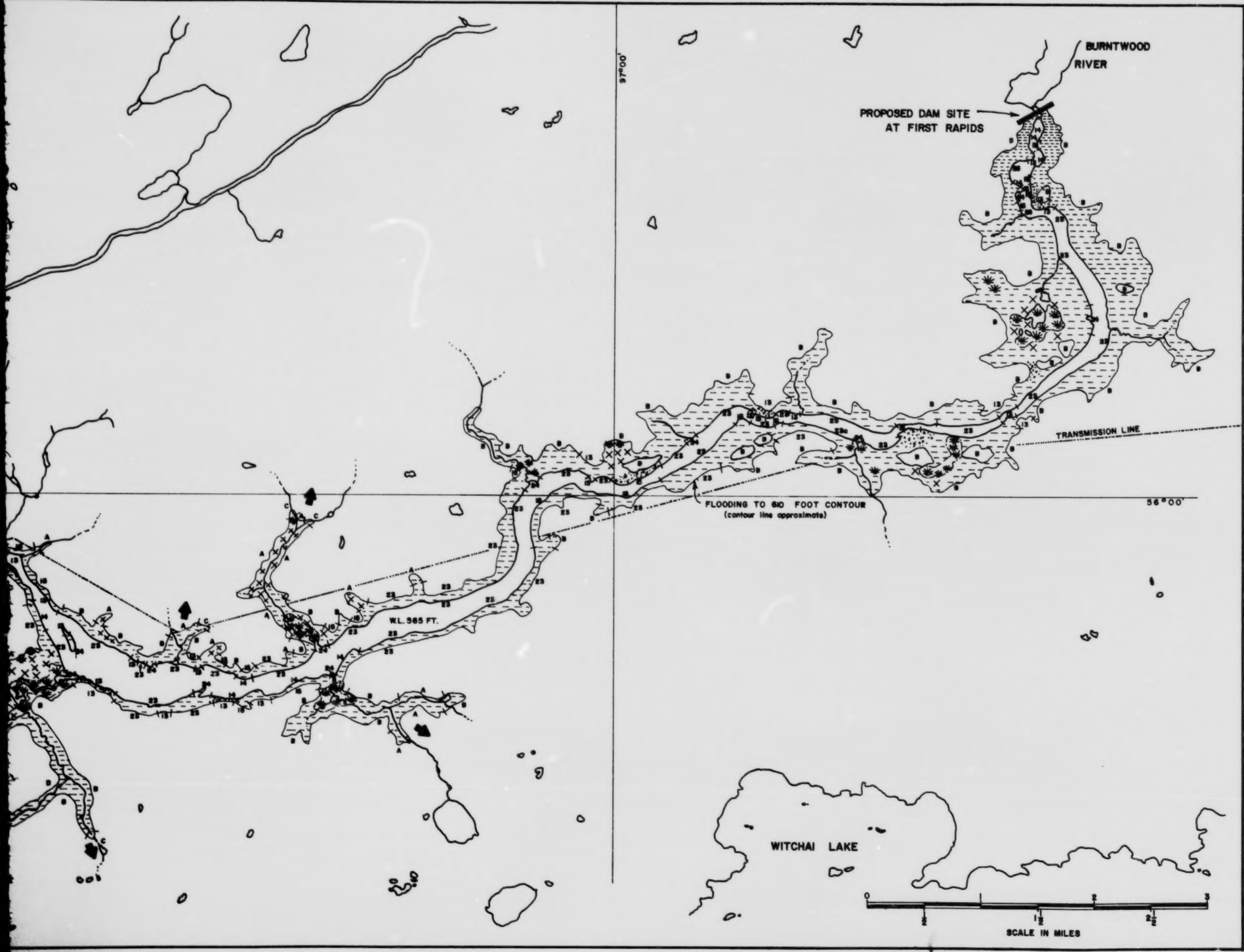
Shorelines: The natural shoreline mileage of the reservoir are as shown in Table 69.

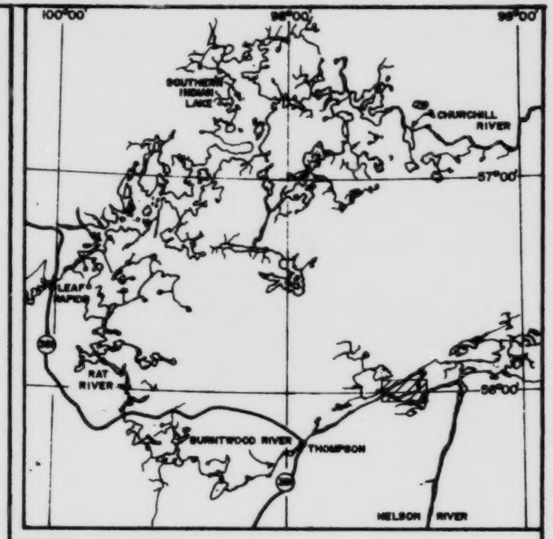
First Rapids differs from the other upstream reservoirs, Wuskwatim and Manasan, in that the reservoir will be formed entirely within a river channel. The channel is characterized by the alternating series of bedrock control (Types 13B, 14 and 15) and clay overburden (Type 23) shorelines. The entire river is controlled in the vertical by bedrock and in the horizontal by bedrock along Type 13B, 14 and 15 shorelines and by alluvial materials along Type 23, 24 and 25 shorelines. Narrow channel sections and headlands are almost entirely bedrock control while widenings in the river are Type 23. Types 13B, 14, 15 and 23 shorelines are represented by 8.3, 4.1, 2.2 and 17.5 miles of shoreline respectively.

Bedrock control shorelines are characterized by the narrower than normal water-washed rock zone. The widest exposed zones are located at rapid sections and headlands. Other bedrock control shorelines are masked by alluvium.

In the natural state, the long sweeping stretches of Type 23 on the south river shore are more active than those of the northern shore. Active clay overburden shorelines (Type 23) are similar to those discussed in Wuskwatim Reservoir and shown in Photograph 159. Stable clay overburden shorelines as shown in Photograph 167 are characteristically sites of deposition. Both point and side silt bars are well established with sedges. Point bars are located at the inside of a river bend while side bars are peculiar to channels with a straight or irregular con-


N
ODEI RIVER
THIRD RAPIDS
SECOND RAPIDS
TRANSMISSION LINE
BURNTWOOD RIVER





LOCATION OF MAP

LOCATION - PLAN

0 20 40 60
SCALE IN MILES

LEGEND

SYMBOL	CLASSIFICATION
	SEDGE COMMUNITIES
	TREED MUSKEG TERRAIN
	TREED MUSKEG TERRAIN WITH PERMAFROST
	GLACIAL DRIFT TERRAIN
	BEDROCK OUTCROPS
	CLAY OVERBURDEN
	FLOODING POSSIBLY GREATER THAN INDICATED
	FLOODING - DIVERSION ONLY
	FLOODING - DAM AND RESERVOIR (PROPOSED)
	DIKES
	OUTLINE OF SEDGE COMMUNITIES

FIG. 178

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH
CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

PHYSICAL IMPACT STUDY
BURNTWOOD RIVER
FIRST RAPIDS RESERVOIR
610 FOOT FOREBAY
SHORELINE AND INUNDATED AREA CLASSIFICATION

PREPARED	DRAWN	CHECKED	
T. M.	R. H.	F. P.	
SCALE	DATE	SHEET NO.	FILE NO.
AS SHOWN	JULY/74	3	61-1-1026

figuration. In most instances an exposed clay zone is evident between the alluvium and tree line on stable shorelines (Photograph 167).

The majority of the 12.4 miles of low alluvial shorelines (Type 24) are located along the streams flowing into the Burntwood River. Alluvial outlets and backstream areas are well established with submerged and emergent aquatics and willows (Photograph 168).

Slumping overburden shoreline (Type 25) are restricted to less than one mile of shoreline. Bank instability was felt to be due more to the height of the overburden than the thawing of permafrost materials.

Inundated Terrain: Forested land comprises the majority of the backshore terrain. Treed muskeg and treed muskeg interspersed with collapse scars make up a small percentage of the area, the majority of the area has been recently burnt over and is still in the early stages of colonization. The undisturbed mixed forest consists of good growth poplar and spruce.

In comparision to the upstream reservoirs-Wuskwatim and Manasan, there are no extensive backshore bogs or collapse scars. The one backshore area, as shown in Photograph 167, exhibiting sedge communities (bogs) appears to be actively collapsing. An interpretation of aerial photos taken over a 20 year period indicates that these bogs are gradually increasing in size. This can be attributed to the gradual thawing of permafrosted materials.

Backshore water bodies (18 acres) are also limited in extent. The only identifiable bodies were in the area shown in Photograph 167.

8.4.4 POST DIVERSION - PRE RESERVOIR CONDITIONS - FIRST RAPIDS RESERVOIR: Under diversion only conditions the mean open water levels of the defined reservoir will be increased by twelve feet while normal ice conditions will raise the diversion only levels on additional nine feet. The open water shoreline is not shown in Figure 178 as the contours were not available. Backshore flooding will largely be restricted to the tributary areas. Moreover, the diversion only shoreline types will not substantially change from the natural state shoreline types as given in Table 69.

Shorelines: The effect of the winter ice levels under diversion conditions on the shorelines will be similar to those already discussed for Wuskwatim and Manasan Reservoirs. An ice scour zone is expected to develop above the open water line along the majority of the shorelines. Under repeated annual surcharges the zone will be devoid of standing trees. Clay shorelines will be colonized by grasses and sedge while bedrock will remain barren.

Under diversion only conditions, the lush marsh zones typical of the tributary streams will be eliminated. The silt bar zones typical of natural shorelines will also be reduced.

In the tributary areas, the new shoreline will rise into a treed lacustrine clay terrain. Such areas will be characterized by dead standing trees.

Inundated Terrain: Under open water diversion only conditions terrain will only be inundated within the tributary areas. In most cases the tributary alluvial shoreline area will be entirely inundated. Incomparison to the upstream reservoirs, there will be very few inundated sedge communities as the well drained slopes are treed.

PHOTOGRAPH 167 - A stable clay overburden shoreline (Type 23) on the Burntwood River. The offshore zone of a stable clay overburden shoreline is colonized with emergent and submerged aquatic plants. The sedge communities (bogs) in the backshore area will be inundated under reservoir conditions.

PHOTOGRAPH 168 - A low alluvial shoreline (Type 24) on the Burntwood River. Under reservoir conditions the shoreline will be contained within the backshore of the bedrock shoreline (left hand corner) while flooding will totally inundate the stream environment.

TABLE 69

FIRST RAPIDS RESERVOIR

Mileages of Shoreline Types Under Natural State Conditions

Classification	13B	14	15	23	24	25	Total
Burntwood River	8.3	4.1	2.2	17.5	12.4	.3	44.8

TABLE 70

FIRST RAPIDS RESERVOIR

Area of Water Under Natural State Conditions is 1929 acres

Areas of Inundated Terrain Between the Natural Shoreline and the 610 Foot Contour

Sedge Communities	228 acres
Forested Land	3,938
Backshore Water Bodies	18
TOTAL	4,185

TABLE 71

FIRST RAPIDS RESERVOIR

Mileage of Shoreline Types for a Forebay Elevation of 610 Feet

Classification	13B	14	15	23	24	25	A	B	C	Total
Mainland	3.0		7.2	9.4			6.6	37.7	.8	64.7
Islands	.3							5.4		5.7
										70.4

8.4.5 IMPACTED RESERVOIR CONDITIONS - FIRST RAPIDS RESERVOIR: Formation of First Rapids Reservoir at the 610 foot forebay elevation will not be as detrimental to the landscape adjacent to the waterway in terms of area inundated as compared to the upstream reservoirs - Manasan and Wuskwatim. The approximate reservoir shoreline and inundated terrain is as shown in Figure 178 and Tables 70 and 71. The 610 forebay contour is only approximate as the 600 foot contour was obtained from a 1:50,000 NTS map. Consequently the reservoir will likely be larger than that shown in Figure 178 particularily in the valley areas.

In classifying the reservoir shorelines, the natural state shoreline backshores were used to indicate the type of shoreline expected to evolve along portions of the reservoir. This particularly pertains to areas of moderate and consistant relief where flooding is contained within the immediate backshore of the existing shoreline. The shoreline area classification system was used where flooding is extensive horizontally and the approximate location of the 610 foot contour was questionable.

The reservoir shorelines will be discussed under the following heading, "Future Shorelines".

Future Shoreline: The actual reservoir shoreline will vary somewhat from those given in Table 71 due to the uncertainty of the exact location of the forebay. Bedrock control shorelines may be more prevalent at the higher elevations as outcroppings are evident in the backshore areas. This may reduce the occurrence of clay overburden shorelines, Type 25 and B. However, higher levels will also extend the flooding horizontally in the valleys thereby increasing the occurrence of Type A and B shorelines. Shorelines predicted to evolve into bedrock control will not likely be affected by slightly higher levels.

The majority of the exposed shorelines are expected to achieve stability within a thirty year period. This is largely due to the elimination of much of the treed cover, the exposed bedrock in the backshore areas and the contained nature of the flooding. It is likely that certain clay shorelines will continue to erode and not fully stabilize, however this is a natural phenomenon in this area. Shoreline instability can also be attributed to the thawing and slumping of permafrost overburden. As permafrost is infrequent, this will be a localized phenomenon. Embayment and stream valley shorelines will not achieve a natural state as soon as those shorelines along the channel.

In general, the shorelines will be cluttered with undercut trees and accumulated debris. The reservoir will act as a catching basin, retaining the debris from the immediate upstream areas.

The ultimate configuration of Type A and B shorelines will largely depend upon the depth of overburden to bedrock and the eroding forces. In this area the majority of the shorelines will likely be clay overburden.

Under reservoir conditions, the offshore area will not contain the alluvium and subsequent marsh zone typical of the rivershores. However, under a normal lake fluctuation regime, a marsh zone may become re-established in certain water-washed zones.

Low relief clay overburden islands exposed to wave action will likely be eroded away.

At the 610 foot forebay elevation, the headpond will flood portions of the existing transmission line extending from Kelsey Generating Station to Thompson. This would likely require relocation of the line in the vicinity of the site.

Inundated Terrain: At the 610 foot forebay, the total acreage of flooded terrain will be greater than that given in Table 70.

Under reservoir conditions, the impact on the sedge communities will be minimal as the majority of the sedge communities as found along the natural tributaries will already have been inundated under diversion-only conditions. The few remaining acres of backshore bogs will likely rise with the water level increment. Trees will remain standing along protected sites for a longer period than those exposed to wave action.

8.4.6 SUMMARY STATEMENT - FIRST RAPIDS RESERVOIR: For the purpose of this report, First Rapids Reservoir extends from the dam site at First Rapids on the Burntwood River upstream a distance of approximately 16 miles to Third Rapids. It is at this point that the water levels under ice cover conditions are similar to those of the backed up reservoir water levels. Formation of the reservoir at the 610 foot forebay will flood out Second Rapids, one mile downstream of Third Rapids, and back the water up one foot (614 to 615) between Third Rapids and Apussigamasi Lake. The reservoir will raise the water levels 36 feet (574 to 610) at First Rapids and 19 feet (591 to 610) between Second and Third Rapids. Under normal open water diversion conditions (34,300 cfs), the reservoir water levels will serve to eliminate the nine foot rise in levels (577 to 586) anticipated to occur between First and Second Rapids under diversion only and normal ice cover conditions. However, levels under ice surcharge conditions are expected to rise eight feet (615 to 623) between Third Rapids and Apussigamasi Lake under reservoir conditions.

In the natural state the channel is characterized by the alternating stretches of clay and bedrock shorelines. Marsh zones are confined to the tributary areas. The shoreline is 45 miles in length.

Under post diversion-pre diversion conditions the majority of the shorelines will be characterized by an ice scour and subsequent herbaceaus vegetation above the mean open water level while the marsh zones typical of tributaries will be reduced in extent.

At the 610 foot forebay, First Rapids Reservoir is approximately 6,114 acres in size and contains approximately 70 miles of shoreline. The area to be inundated consists mostly of burnt over treed terrain.

Shorelines that are contained within the backshore area of the natural shoreline will stabilize the soonest. Bedrock shorelines will be achieved once the overburden is eroded while the clay overburden shorelines along the channel will appear much as they did in the natural state. Some of the shorelines will fall directly into exposed bedrock. However, the majority of the shorelines that extend beyond the natural shoreline backshore area. Exposed shorelines will continually erode until they stabilize. Active slumping will occur along the clay shorelines where flooding has caused permafrosted materials to thaw. Protected shorelines will remain congested with standing and fallen trees.

At the 610 forebay elevation, portions of the transmission line extending from Kelsey Generating Station to Thompson will be flooded.

APPENDIX 2 - VOL. 1 - B

LAKE WINNIPEG SHORELINE EROSION, SAND MOVEMENT AND ICE EFFECTS STUDY

LAKE WINNIPEG, CHURCHILL AND
NELSON RIVERS STUDY BOARD

LAKE WINNIPEG SHORELINE EROSION, SAND MOVEMENT, AND ICE EFFECTS STUDY

PREPARED BY:

F. PENNER, P. ENG.,
A. SWEDLO, P. ENG.,
GEOTECHNICAL SECTION,
PLANNING DIVISION,

WATER RESOURCES BRANCH,

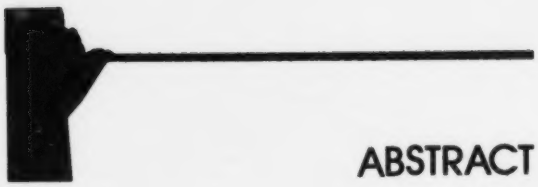
DEPARTMENT OF MINES, RESOURCES
AND ENVIRONMENTAL MANAGEMENT,

PROVINCE OF MANITOBA

WINNIPEG, MANITOBA
JULY, 1974

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.



ABSTRACT

A study of the shoreline processes on the south pool of Lake Winnipeg was conducted under a joint Federal-Provincial agreement to determine the effects arising from Lake Winnipeg water level regulation. The study provides historic data and on the basis of this data predicts the effects (both immediate and long range) of water level regulation on shoreline erosion (or shoreline advance), sand movement and the effects of ice on the shoreline and shoreline structures.

Historic rates of shoreline erosion were determined by superimposing on a plan the location of the shoreline at several points in time. The amount of shoreline adjustment due to the effect of lake level regulation was determined utilizing an equilibrium shore profile concept. On the basis of this concept, the shore profile is related to the wave climate and water level regime. Any change in the water level regime causes a corresponding vertical and horizontal shift in the shore profile if the wave climate remains the same. The wave climate (waves, winds and wind set-up) was developed from three seasons of field observations. Two models relating the rate of erosion to lake level and wave climate were used to determine upper and lower time limits required for the profile shifts to occur. Land loss and sediment generated computations were also performed.

The sand regime was determined by field surveys at selected cross-sections. The potential rate and directions of sand movement were determined from the wave climate observations and a sand movement capacity relationship developed by the U.S. Army Corps of Engineers. The results were verified where possible by field evidence. A prediction of the immediate and long term effects of lake level regulation on the sand regime is made.

Historic ice effects on the shoreline and shoreline structures were assessed on the basis of field evidence and office studies of ice expansion factors, wind driven ice forces, up-slope ice travel distance and height of ice-mound calculations. This data was then used to estimate the effect of regulation on the shoreline and shoreline structures.

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Note: All Figures and Tables referred to in the summary report can be found in the comprehensive report.

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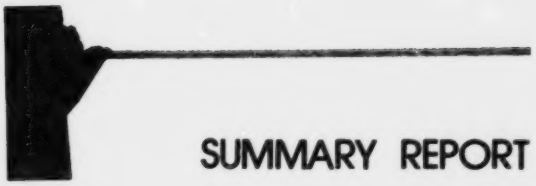
summary report



SUMMARY REPORT

I. OBJECTIVES

The objectives of this Study were as follows:

1. Determine the rate of shoreline recession under recorded lake level conditions.
2. Determine the effect of regulated lake levels on shoreline recession.
3. Study and propose means to enhance the benefits with respect to shoreline erosion and means to mitigate the damages with respect to shoreline erosion due to regulated lake levels.
4. Determine the characteristics of the sand regime at beaches and along the shoreline under recorded lake level conditions.
5. Determine the effect of regulated lake levels on the sand regime.
6. Study and propose means to enhance the benefits with respect to the sand regime and means to mitigate the damages with respect to the sand regime due to regulated lake levels.
7. Study the effects of ice on the shoreline, shoreline vegetation and shoreline structures under recorded lake level conditions.
8. Determine the effects of regulated lake levels on ice effects.
9. Study and propose means to enhance the benefits with respect to ice effects and means to mitigate the damages with respect to ice effects due to regulated lake levels.

II. RECOMMENDATIONS

On the basis of this Study it is recommended that the appropriate authorities consider the following course of action:

1. Formulate land use and development plans for shoreline lands recognizing:
   - that future erosion will be similar to past erosion in absence of protective structures,
   - that protective works arresting erosion have secondary effects on fronting beaches and water depths which effects depend on type of structure,
   - the desirability of differing land use for different shoreline areas.

2. Construct several pocket beaches of imported sand and protected by groin type structures for the purpose of:
   - demonstrating the technical and economic feasibility and benefits of such structures,
   - confirming and refining design criteria for such structures.

3. Develop, publish and distribute a Lake Winnipeg Shoreline Handbook for the purpose of:
   - providing interested citizens with information on lake levels and rates of shoreline recession,
   - stimulating and assisting lake shore property owners to construct and maintain suitable shoreline protective works which are within their financial ability or at the very least to discourage them from constructing unsuitable works.

The Handbook would contain:
   - basic data on lake levels
   - data on shoreline recession
   - a brief simple description of processes affecting sand beaches
   - a brief description of ice effects
   - simple and typical designs and spe-

cifications for shoreline protective works which the owner or a local contractor could construct

4. Consider the immediate construction of a lined boat channel through the opening in the sand bar between Victoria and Hillside beaches and filling in the opening up to the edge of the channel. The purpose of this project would be to demonstrate the feasibility of artificially accelerating the extension of the sand bar and the formation of beaches.

5. Take no action relating to ice effects other than to comment on it in proposed Handbook.

III. TERMS OF REFERENCE

A. Canada-Manitoba Study Agreement

The Canada-Manitoba Agreement for Lake Winnipeg and the Churchill and Nelson Rivers provides, among other things, for studies to determine the effects that regulation of the level of Lake Winnipeg by outlet control works is likely to have on other water and related resource uses and to make recommendations for enhancing the overall benefits with due consideration for protection of the environment. The studies are to provide reliable data on present natural conditions and the anticipated and actual conditions arising from the operation of the controls as designed and constructed. Among the effects on the water regime are related effects on shoreline erosion and sediment movement patterns in the larger lakes affected by regulation.

B. Study Limited to Southern Portion of Lake Winnipeg

The Study has been limited to the southern portion of Lake Winnipeg because:

- the shoreline lands here have been intensively developed. In contrast, the shoreline of the northern portion has been developed at only a few widely separated settlements.
- financial and time constraints required that the work be concentrated in areas where the effects would be experienced by people at the earliest possible time.
- data relationships established for the southern portion could as required, be extrapolated and projected to the northern portion at a later date.

A Key plan of the Study Area is included as Figure 1.

C. Erosion Study

The erosion study is limited to determining the rate of shoreline erosion (or shoreline recession) and to identifying the factors influencing this rate. The secondary effects of erosion such as the effect of turbidity due to suspended sediment are not considered. An exception is the generation of beach sands as a product of shoreline erosion. Additionally, enhancement and mitigation measures are considered.

D. Sand Movement Study

The sand movement study is limited to determining the distribution of sand along the shoreline and identifying the factors influencing the distribution and movement of the sand. In addition, enhancement and mitigation measures are considered.

E. Ice Effects Study

The ice effects study is limited to the effect of ice on the shoreline, shoreline vegetation and shoreline structures. Enhancement and mitigation measures are also considered.

F. Man-Made Changes Already Affecting the Levels of Lake Winnipeg

Water levels previously recorded on Lake Winnipeg cannot accurately be described as "natural levels", because man-made works on tributary rivers have affected river flow patterns and hence, lake levels. Man-made changes have been introduced over a period of time; moreover water has been removed from some rivers and water has been added to other rivers. Therefore, for the purpose of this study it is necessary to recognize and define three lake level conditions.

1. Recorded Lake Levels: These are actual water levels recorded by gauges at Winnipeg Beach (1913-July 1966) and at Gimli (August 1966-1973). They are sometimes termed "historic levels". For reasons stated earlier they are not strictly "natural levels" and not a true picture in themselves of future levels which would apply if past rainfall were to recur.

2. Unregulated Lake Levels: These are lake levels which would have occurred if precipitation were the same as has been recorded in the past and all of the present man-made control works had been in existence and had been operated in accordance with present operating rules. The term "unregulated" refers to the outflows. These are sometimes termed "historic" lake levels modified according to "present use" or simply "modified historic" levels.

3. Regulated Lake Levels: These are essentially the unregulated lake levels modified according to the regulation of the level of Lake Winnipeg by the outlet control works at Jenpeg to meet specified future power demands with a specified sequence of development (sequence C1J-A) of other generating facilities. The term "regulated" refers to the outflow.

G. Definition of Effects of Regulation

For purposes of this report, the effects attributable to regulation are defined to be the effects resulting from the difference between the "unregulated lake levels" and the "regulated lake levels". The anticipated actual effects are those arising from "recorded levels" and "regulated levels". Thus the effects attributable to regulation are not necessarily identical to the anticipated actual effects.

IV. STUDY AREA

A. Location

The study was confined to the southern portion of Lake Winnipeg - south of Riverton on the west shore and south of Elk Island on the east shore. This portion of the lake is approximately 42 miles long in the north-south direction and 16 to 26 miles wide in the east-west direction. The depth of water increases from about 15 feet in the south to 40 feet in the north. A plan of the study area with surface and underwater contours is included as Figure 5.

B. Ice Conditions

The lake is ice free from about May 8 to November 22. The time of spring break-up and the time of fall freeze-up may vary by about one week from the dates given. The ice processes and ice effects are dealt with in the section under the ice effects study.

C. Lake Levels

The recorded levels of Lake Winnipeg are summarized in the following table from a period of record, 1913 - 1973.

TABLE 1
RECORDED LAKE LEVELS

Extreme Daily Low:	708.6 October 29, 1940
Extreme Daily High:	718.9 September 5, 1966
Extreme Instantaneous High:	719.8 September 5, 1966
Extreme Monthly Low:	709.6 February, 1941
Extreme Monthly High:	717.5 July, 1966
Long Term Mean:	713.2

In any year the monthly mean water level typically reaches a peak in July and then drops about one foot to a minimum in December. The annual mean level may change as much as two feet from one year to the next as a result of changes in inflow.

The projected levels of the lake under regulated conditions are within the range of the recorded levels. In general, regulation of the lake will narrow the range of fluctuation by eliminating both extreme low and extreme high levels and will raise the mean open water level by about one foot. In addition, the water level would remain fairly constant from July to November instead of dropping about one foot as under recorded conditions.

D. Wave Action

The results of wave measurements made as part of this study are summarized in the following table.

TABLE 2
SIGNIFICANT WAVE HEIGHTS ON SOUTH POOL OF LAKE WINNIPEG

% of Time Waves Are Greater Than Stated	Significant Wave Height	Wave Period
50%	1 foot	3 seconds
10%	3 feet	4 seconds
1%	6 feet	6 seconds

A seasonal bias has been observed in wave action. Wave action is more severe in fall than in spring.

E. Soils Along the Shoreline

The soil profile along the west shore consists of a shallow depth (1 to 20 feet) of lacustrine clay underlain by clay till. Bedrock does not outcrop along the shore profile. The lacustrine clay is stone free and highly erodible. The till contains significant quantities of sand, gravel and boulders. The quantity of coarse particles - sand, gravel and boulders - remaining after the fine grained particles

have been washed away varies along the shore. Where till ridges outcrop along the shore, this quantity is sufficient to provide a continuous cover on the beach and to retard or inhibit further erosion. The elevation of the land adjacent to the shoreline varies from 720 to 740.

The elevation of land fronting on the south shore is at or near the lake level, except for an almost continuous sand dune which has developed behind the sand beach. The soils underlying the beach and sand dunes are lacustrine clays and silts. Some areas have extensive peat cover.

The soils along the east shore are more variable and complex. These include glacial outwash deposits consisting mainly of sands, lacustrine clays and silts, and boulder rich clay tills. Most of the headlands on the east side are clay tills armoured with large boulders. Only at the southwest corner of Elk Island does bedrock outcrop above the water level. The elevation of land fronting on the east shore varies from about 720 at the south to about 770 at Elk Island.

F. Shoreline Development

The land along the west shore has been developed for agriculture and cottages. The land along the south shore is largely undeveloped because it is subject to flooding, has virtually no backshore and has poor access. The land along the east shore is rapidly being developed for cottages. In 1971, there were about 6000 seasonal residences within 1 mile of Lake Winnipeg, of which 1200 fronted directly on the lake. The market value of these 6000 cottages was about $22.2 million. In addition there were approximately 2000 resident and commercial properties with a market value of about $25.5 million within one mile of the shoreline.

V. METHODOLOGY FOR SHORELINE EROSION STUDY

A. Determination of Historic Rates of Shoreline Recession

Historic rates of shoreline recession were determined by plotting on a plan the location of the shoreline as it existed at several different points in time and as derived from land subdivision surveys and aerial photographs. These rates are summarized on Figures 11-1 to 11-5.

B. Determining Effect of Regulation on Shoreline Erosion

The effect of regulating the level of the lake on shoreline erosion was deduced utilizing the concept of the equilibrium shore profile. This concept postulates that the shore profile is related to the wave climate and water level regime and that any change in the water level regime causes a corresponding shift in the shore profile if the wave climate remains constant. If the water level rises the shore profile shifts upward and landward to maintain a constant position relative to the water level.

Since the water levels under any condition are variable, it is necessary to represent the variable levels for each condition by an equivalent single level hereafter defined to be the effective lake level which may be associated with the shore profile for that condition. The change in the equivalent level is then a measure of the vertical profile

shift to be associated with a change from one lake level condition to another lake level condition. The horizontal profile shift associated with the vertical shift depends upon the shape of the profile and on whether soil eroded from one part of the profile is deposited on the offshore part of the profile. The effective lake level was further defined as a constant level at which the rate of erosion would be the same as under the actual variable levels and was computed on the basis of a model relating the rate of erosion to lake level, wind set-up, wave height and shore profile. The computations utilized a wave energy and wind set-up climate developed on the basis of three seasons of field observations.

The initial change in the rate of erosion following regulation was estimated using the model mentioned earlier. It was postulated that the initial increased rate would decrease to the historic rate as the vertical and horizontal profile shifts occurred.

Upper and lower limits for the time required for the profile shifts were estimated using two erosion-time models. It was not possible to determine the most probable time between these two limits.

Upper and lower limits for the proportion of the profile shift attributable as a cost to regulation were also computed on the basis of the two erosion time models.

VI. METHODOLOGY FOR SAND MOVEMENT STUDY

A. Inventory of Beach Sand Volumes

The volume of sand along the shoreline was determined by field surveys at selected cross-sections.

B. Analysis of Sand Transport Rates

The potential rate and direction of sand transport along the shore was determined from wave energies utilizing a relationship developed by the U.S. Army Corps of Engineers. Rates and directions were verified where possible by field evidence.

C. Determining Effect of Regulation On Sand Beaches

The shift in the beach profiles due to regulation was computed as outlined earlier for the general shoreline case.

The initial change in exposed beach due to the change in lake level was estimated from the average beach slope and change in lake level.

It was considered that the initial increase in wave energy reaching the shoreline would cause an increase in the rate of long shore movement of sand and an increase in the rate of generation of sand as an erosion product. The net effect was considered to be a minor change in the amount of sand.

VII. METHODOLOGY FOR ICE EFFECTS STUDY

The methodology for evaluating the effect of regulation on ice effects involved a review of general lake ice processes, an evaluation

of the effects of regulation on shore ice and ice pile-up along the shoreline using analytical computations and a survey of historical damages by interviewing older lake shore residents.

VIII. OBSERVATIONS AND CONCLUSIONS

A. Historic Rates of Shoreline Recession

Historic longterm average shoreline recession rates were derived from analysis of available land survey plans and aerial photographs as illustrated in Figure 10. The shoreline within the Study area was found to be generally eroding at rates of typically one to two feet per year with extreme values of zero to 25 feet per year. Historic recession rates around the perimeter of the Lake are summarized on Figures 11-1 to 11-5. Only at artificial littoral drift barriers such as docks and breakwaters was an advance of the shoreline, due to accretion of sand, observed. The erosion is attributable to the type of soil - clays, clayey to sandy tills, and outwash sands - forming the shoreline and to a long term rise in the level of the south pool resulting from continuing isostatic rebound of the northern outlet of the lake.

The land loss associated with the recorded erosion process amounts to some 15 acres per year. Excluding the marsh at the south end, the average annual loss of land along reaches of shoreline defined on Figure 16 is given in table 11.

Sediment generated by the erosion process amounts to some 510,000 tons per year, consisting 278,000 tons of silts and clays and 232,000 tons of sands, gravels and boulders. These values may be compared to some 2,650,000 tons per year of suspended sediment contributed by the Red River, consisting of approximately 2,570,000 tons of silts and clay and 80,000 tons of sand. The volume of silt and clay sediment generated by shoreline erosion process is roughly ten percent of the volume of silt and clay sediment contributed by the Red River.

B. Effect of Regulation on Shoreline Recession

Regulating the level of the Lake by outlet control works is estimated to cause an initial increase in the rate of shoreline recession of approximately 50 percent. The rate is then expected to decrease linearly with time and to approach the rates for equilibrium conditions as the shore profiles adjust to the new higher water levels. That is, along the east and west shorelines the rate of land loss will increase initially from the equilibrium rate of 15 acres per year to 23 acres per year for an average rate during the profile adjustment period of 19 acres per year.

The adjustment of the shore profile to the new higher water levels will result in a profile rise of typically 0.3 to 0.5 feet and a landward profile shift of typically 5 to 75 feet. The total area of land associated with this profile adjustment along the east and west shoreline is approximately 312 acres. Detailed data are given in Table 9 for the reaches defined on Figure 16.

The time required to effect the profile adjustments and the proportion of the profile shift which may be considered as a damage attributable to the regulation of the Lake level depends on the erosion-time model used in the analysis. The current state of the art of shoreline engineering is not adequate to ascertain the degree to which the two proposed models apply.

The model giving the lower limits (Case 1) suggests the profile shift would occur over a period of typically 5 to 40 years and that approximately 20 percent (62.5 acres) of the land loss associated with the profile shift would be attributable to the regulation of the Lake level. On this basis the weighted average time to effect the profile adjustments is approximately 16 years.

The model giving the upper limits (Case 2) suggests the profile shift would occur over a period of typically 20 to 200 years and implies that 100 percent (312 acres) of the land loss associated with the profile shift would be attributable to the regulation of the Lake level. On this basis the weighted average time to effect the profile adjustments is approximately 80 years. It should be noted that the total land loss during this time period would be approximately 1500 acres. A summary of the time for profile adjustments is given in Table 10.

The volume of sediment generated as a result of the total profile adjustment from recorded to regulated is estimated to be 8,800,000 tons, consisting of 6,000,000 tons of silt and clay and 2,800,000 tons of sand, gravels and boulders. This may be compared to an average annual sediment load in the Red River of 2,570,000 tons of silt and clay and 80,000 tons of sand.

C. Mitigation of Damages and Enhancement of Benefits With Respect to Shoreline Erosion

Where shoreline development planning or existing developments require the arresting of the erosion process, consideration should be given to the use of artificial sand beaches confined by groin type structures to provide both erosion protection and recreational facilities. The narrowing of the range of lake levels and the reduction of peak levels would make the design of such structures less costly and more practical.

D. Availability of Sand Around Shoreline

The west shore is deficient in sand for beaches except at Gimli and Winnipeg Beach. The lack of sand reduces the recreational capability of the shoreline and also contributes to increased erosion of the predominantly clay shoreline.

Portions of the south shoreline have extensive volumes of sand below the water level. Beach ridges and dunes above the water level are generally not extensive and are backed by low lying marshy land. Development of these sand deposits for beaches is likely possible but would require extensive and costly dredging of sand.

Excellent sand beaches exist along the east shore at Patricia Beach, Grand Beach, Hillside Beach, Victoria Beach and Albert Beach and Elk Island. Patricia, Grand and Hillside Beaches are bay mouth bars with sand dunes back of the beach. The Victoria and Elk Island beaches are formed by the

erosion of sandy bluffs. However there are extensive reaches of shoreline with boulder and cobble beaches.

E. Effect of Regulation on Sand Beaches

Along the west shore the increase in wave energy reaching the shoreline during the profile adjustment stage is expected to increase the rate at which sand is transported along the shore. Concurrently the generation of sand as an erosion product will increase as well. It is believed that the two effects will compensate each other and that the net effect will be a minor change in the availability of sand - in some areas an increase and in others a decrease.

Along the south shore and at Patricia Beach the profile adjustment associated with regulation of the Lake level is expected to cause the shoreline to recede approximately 50 feet over a period of time estimated to be in the range of 10 to 50 years.

At Grand Beach, Hillside Beach, Victoria Beach and Elk Island the profile adjustment associated with regulation of the Lake level is estimated to cause the shoreline to recede some 5 to 10 feet over a period of 5 to 25 years.

F. Mitigation of Damages and Enhancement of Benefits With Respect to Sand Beaches

In the case of eroding sandy bluffs it is considered best to permit the erosion associated with the profile adjustment to take place. Attempts to stop the erosion are likely to impair the sand beach. The recession of the top of the bank will generally not be great enough to cause major damage to existing developments.

In the case of bay mouth bar beaches such as those at Patricia, Grand and Hillside Beaches the profile adjustment will cause a loss of beach sand from the dunes which could only be replaced by dredging offshore sand. The feasibility and economics of such measures require further study.

As noted earlier, the narrowing of the range of lake levels during the open water season would simplify the design and reduce the cost of artificial beaches.

G. Historic Shoreline Damage Due to Ice Effects

Analytical computations and a survey of lakeshore residents indicate that shoreline damage due to ice effects is uncommon and requires an unusual combination of circumstances. The lack of damage is partly attributable to the fact that people recognize wave and ice action to be severe and therefore do not construct light docks and boat houses which would be damaged.

H. Effect of Regulation of the Lake on Shoreline Damage by Ice

It is anticipated that regulation of the level of the lake will cause a modest reduction in shoreline damage by ice. This would be a minor change in a phenomenon of minor importance.

The conclusions derived from the field evidence concur with those derived from analytical computations and may be summarized as follows:

1. Ice shove due to the thermal expansion of the ice sheet does not cause significant damage.
2. During the spring ice break-up period, ice pile-up due to wind forces is common. However, the pile-up normally occurs offshore or on the beach and does not damage buildings or trees.
3. High mounds of ice pile-up are normally associated with wind acting on a wide ice sheet pushing against a narrower structure or shoreline.
4. Damage to shoreline buildings appears to have a frequency of once or less in a lifetime and depends on a rare combination of high onshore winds (say greater than 30 m.p.h) from a narrow sector (say 45°) during a short interval of time (say 2 weeks) together with the multiplier effect on a long ice sheet acting on a short shoreline. Additionally, the water level must be sufficiently high so that the ice piles up near enough to the shoreline to damage shore structures.
5. The lower spring lake levels in comparison to the fall lake levels will result in reduced onshore ice piling and reduced damage to beaches and beach works.

CHAPTER 1

RECOMMENDATIONS

On the basis of this Study it is recommended that the appropriate authorities consider the following courses of action:

1. Formulate land use and development plans for shoreline lands recognizing:
   - that future erosion will be similar to past erosion in absence of protective structures,
   - that protective works arresting erosion have secondary effects on fronting beaches and water depths which effects depend on type of structure,
   - the desirability of differing land use for different shoreline areas.

2. Construct several pocket beaches of imported sand and protected by groin type structures for the purpose of:
   - demonstrating the technical and economic feasibility and benefits of such structures,
   - confirming and refining design criteria for such structures.

3. Develop, publish and distribute a Lake Winnipeg Shoreline Handbook for the purpose of:
   - providing interested citizens with information on lake levels and rates of shoreline recession,
   - stimulating and assisting lake shore property owners to construct and maintain suitable shoreline protective works which are within their financial ability or at the very least to discourage them from constructing unsuitable works.

The Handbook would contain:
   - basic data on lake levels
   - data on shoreline recession
   - a brief simple description of processes affecting sand beaches
   - a brief description of ice effects
   - simple and typical designs and specifications for shoreline protective works which the owner or a local contractor could construct

4. Consider the immediate construction of a lined boat channel through the opening in the sand bar between Victoria and Hillside beaches and filling in the opening up to the edge of the channel. The purpose of this project would be to demonstrate the feasibility of artificially accelerating the extension of the sand bar and the formation of beaches. It would serve as a pilot project for the work proposed in Recommendation 5.

5. Consider further the desirability and feasibility of constructing in the near future a causeway between Victoria Beach mainland and Elk Island to provide access to Elk Island and to promote the formation of further beaches. Evidence suggests substantial quantities of sand are being dispersed and effectively lost by water washing through this opening.

6. Take no action relating to ice effects other than to comment on it in proposed Handbook.

CHAPTER 2

OBJECTIVES

The objectives of this Study were as follows:

1. Determine the rate of shoreline recession under recorded lake level conditions.

2. Determine the effect of regulated lake levels on shoreline recession.

3. Study and propose means to enhance the benefits with respect to shoreline erosion and means to mitigate the damages with respect to shoreline erosion due to regulated lake levels.

4. Determine the characteristics of the sand regime at beaches and along the shoreline under recorded lake level conditions.

5. Determine the effect of regulated lake levels on the sand regime.

6. Study and propose means to enhance the benefits with respect to the sand regime and means to mitigate the damages with respect to the sand regime due to regulated lake levels.

7. Study the effects of ice on the shoreline, shoreline vegetation and shoreline structures under recorded lake level conditions.

8. Determine the effects of regulated lake levels on ice effects.

9. Study and propose means to enhance the benefits with respect to ice effects and means to mitigate the damages with respect to ice effects due to regulated lake levels.

CHAPTER 3

TERMS OF REFERENCE

A. CANADA-MANITOBA STUDY AGREEMENT

The Canada-Manitoba Agreement for Lake Winnipeg and the Churchill and Nelson Rivers provides, among other things, for studies to determine the effects that regulation of the level of Lake Winnipeg by outlet control works is likely to have on other water and related resource uses and to make recommendations for enhancing the overall benefits with due consideration for protection of the environment. The studies are to provide reliable data on present natural conditions and the anticipated and actual conditions arising from the operation of the controls as designed and constructed. Among the effects on the water regime are related effects on shoreline erosion and sediment movement patterns in the larger lakes affected by regulation.

B. STUDY LIMITED TO SOUTHERN PORTION OF LAKE WINNIPEG

The Study has been limited to the southern portion of Lake Winnipeg because:

- the shoreline lands here have been intensively developed. In contrast, the shoreline of the northern portion has been developed at only a few widely separated settlements.
- financial and time constraints required that the work be concentrated in areas where the effects would be experienced by people at the earliest possible time.

- data relationships established for the southern portion could as required, be extrapolated and projected to the northern portion at a later date.

A key plan of the study area is included as Figure 1.

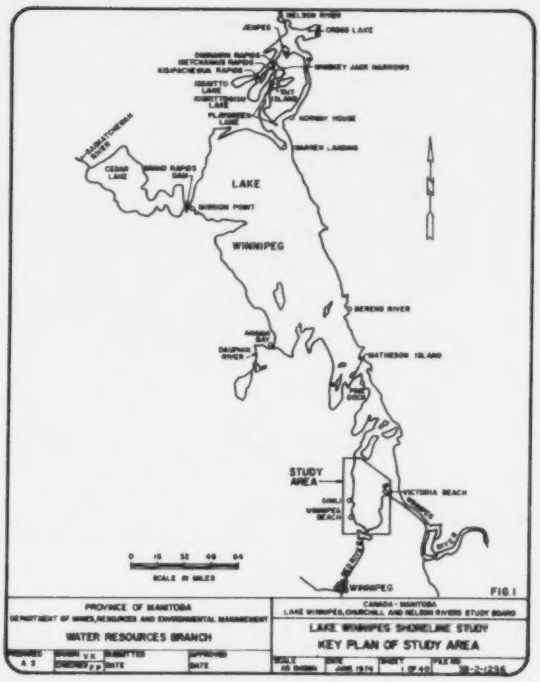


Figure 1 Key Plan of Study Area

C. USE OF DATA BY OTHERS

The information obtained by this study is also intended as input for other related concurrent and possibly future studies. The volume of data generated and utilized in this study is too great to be included in this report. Typical examples of data are included to indicate the type and format of data available.

D. EROSION STUDY

The erosion study is limited to determining the rate of shoreline erosion (or shoreline recession) and to identifying the factors influencing this rate. The secondary effects of erosion such as the effect of turbidity due to suspended sediment are not considered. An exception is the generation of beach sands as a product of shoreline erosion. Additionally, enhancement and mitigation measures are considered.

E. SAND MOVEMENT STUDY

The sand movement study is limited to determining the distribution of sand along the shoreline and the factors influencing the distribution and movement of the sand. Enhancement and mitigation measures are also considered.

F. ICE EFFECTS STUDY

The ice effects study is limited to the effect of ice on the shoreline, shoreline vegetation and shoreline structures. In addition, enhancement and mitigation measures are considered.

G. DEFINITION OF RECORDED, UNREGULATED AND REGULATED LAKE LEVELS

1. PRESENTATION OF LAKE LEVEL DATA. Because the level of the lake at any one point on its surface varies with time, it is customary to present level data in the form of a stage-duration curve of mean monthly levels. This graph indicates the percentage of time that the mean level for a specified month will be

below a specified level. This form of presentation reduces the data to a manageable form and largely eliminates the effect of wind on lake levels. Figure 2-1 is an example of a stage-duration curve.

2. OPEN WATER SEASON. Since erosion and sand movement occur only during open-water (ice-free) conditions existing between approximately May 15 to November 15, only levels occurring during this period were considered to be significant for the shoreline erosion and sand movement investigations. The mean dates of spring breakup and fall freeze-up are May 8 and November 22 respectively. However, to simplify calculations the period May 15 to November 15 was used.

3. HYDROLOGIC BASE PERIOD OF RECORD. Since precipitation, stream flow and lake levels also fluctuate over cycles of several years duration, it is necessary to use as a basis for subsequent computations historic data acquired over some period of time. Manitoba Hydro has used the period November 1927 to October 1966 as basis for computations. This period, referred to as the hydrologic base period 1928-66 has been adopted for this study as well.

4. MAN-MADE CHANGES ALREADY AFFECTING THE LEVELS OF LAKE WINNIPEG. Water levels previously recorded on Lake Winnipeg cannot accurately be described as "natural levels", because man-made works on tributary rivers have affected river flow patterns and hence, lake levels. Man-made changes have been introduced over a period of time. Moreover, water has been removed from some rivers and water has been added to other rivers. For purpose of this study, it is, therefore, necessary to recognize and define three lake level conditions.

(a) Recorded Lake Levels. These are actual water levels recorded by gauges at Winnipeg Beach (1913 - July 1966) and at Gimli (August 1966 - 1973). They are sometimes termed "historic levels". For reasons stated earlier they are not strictly "natural levels" and not a true picture in themselves of future levels which would apply if past rainfall were to recur.

A plot of recorded mean monthly water levels for the period 1927 to 1973 is included in Figure 3. Stage-duration curves of recorded mean monthly levels for the hydrologic base period 1928-66 are included on Figures 2-1 to 2-12.

(b) Unregulated Lake Levels. These are lake levels which would have occurred if precipitation were the same as has been recorded in the past and all of the present man-made control works had been in existence and had been operated in accordance with present operating rules. The term "unregulated" refers to the outflows. These are sometimes termed "historic" lake levels modified according to "present use" or simply "modified historic" levels.

Stage-duration curves of unregulated mean monthly levels computed on the basis of the hydrologic period 1928-66 are included on Figures 2-1 to 2-12.

(c) Regulated Lake Levels. These are essentially the unregulated lake levels modified according to the regulation of the level of Lake Winnipeg by the outlet control works at Jenpeg to meet specified future power demands with a specified sequence of development (sequence GlJ-A) of other generating facilities. The term "regulated" refers to the outflow.

Stage-duration curves of regulated mean monthly lake levels computed on the basis of the hydrologic period 1928-66 are included on Figures 2-1 to 2-12.

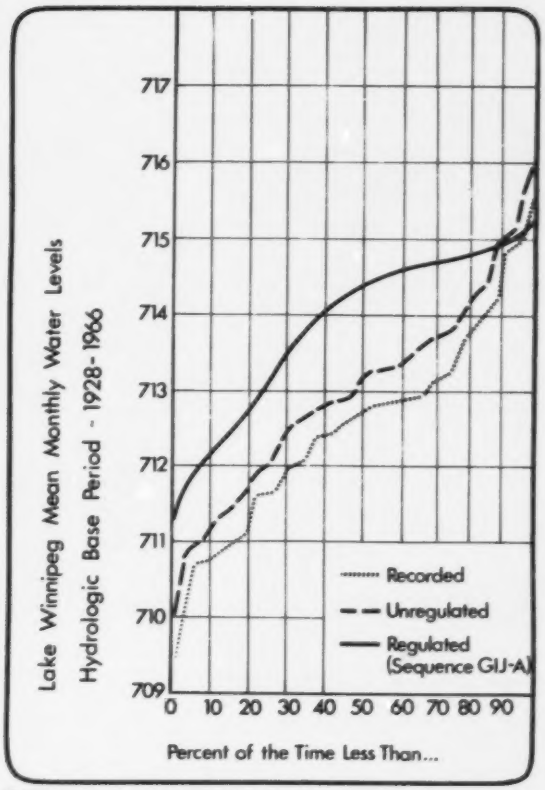


Figure 2-1 - Stage-duration curve - January -

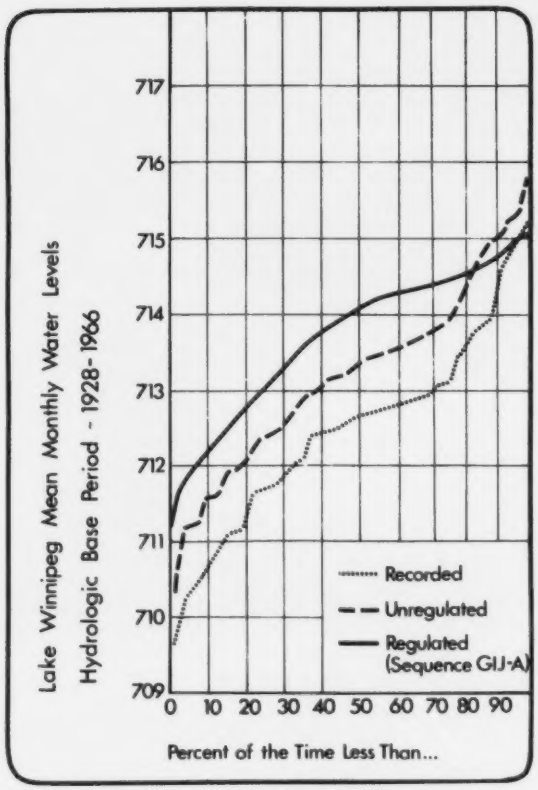


Figure 2-3 - Stage-duration curve - March -

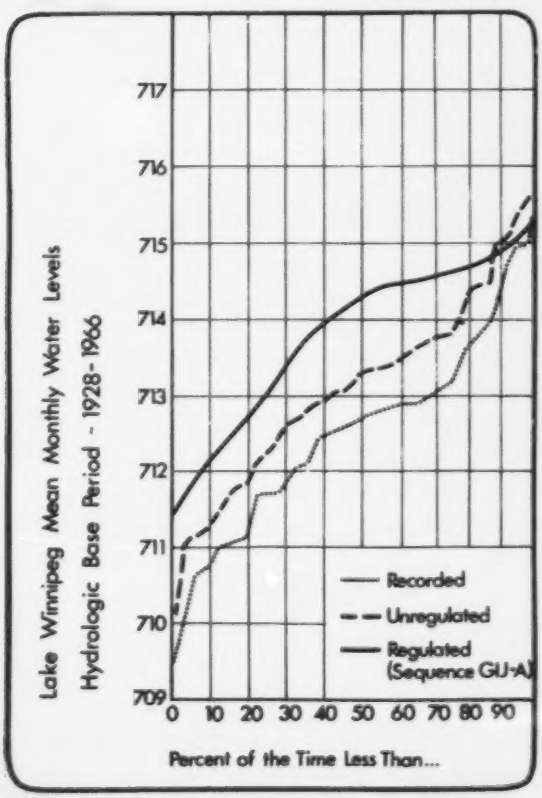


Figure 2-2 - Stage-duration curve - February -

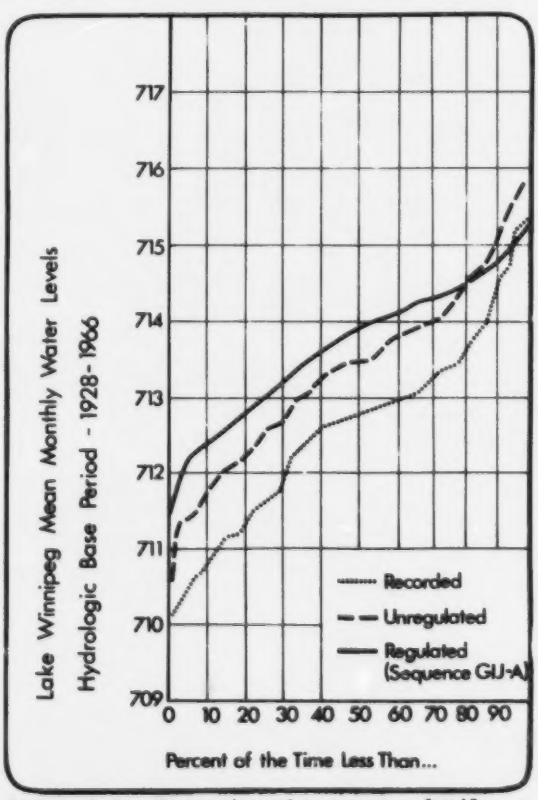


Figure 2-4 - Stage-duration curve - April -

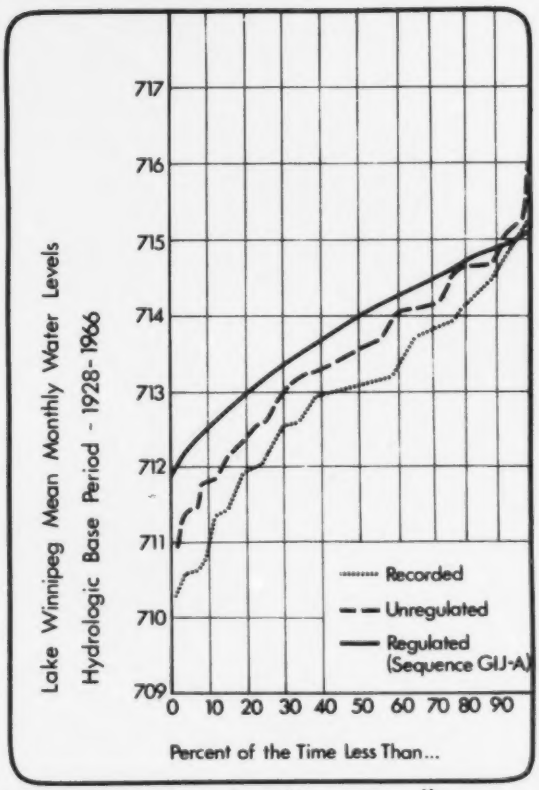


Figure 2-5 - Stage-duration curve - May -

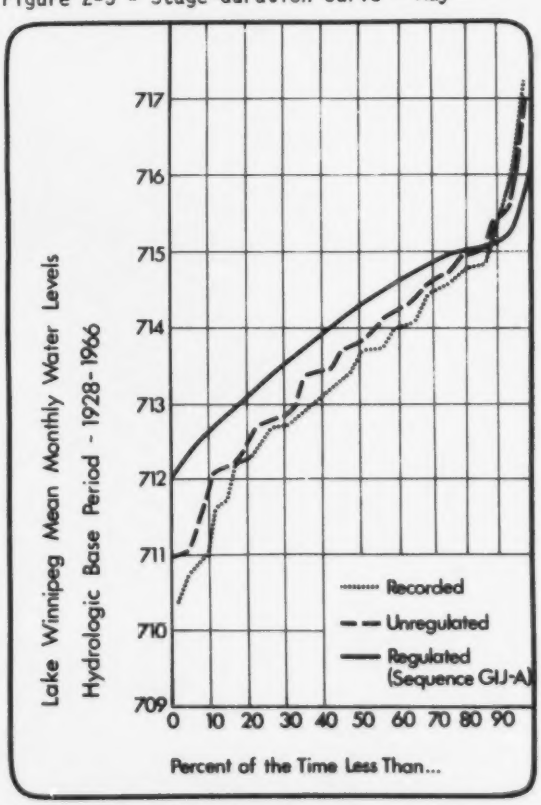


Figure 2-6 - Stage-duration curve - June -

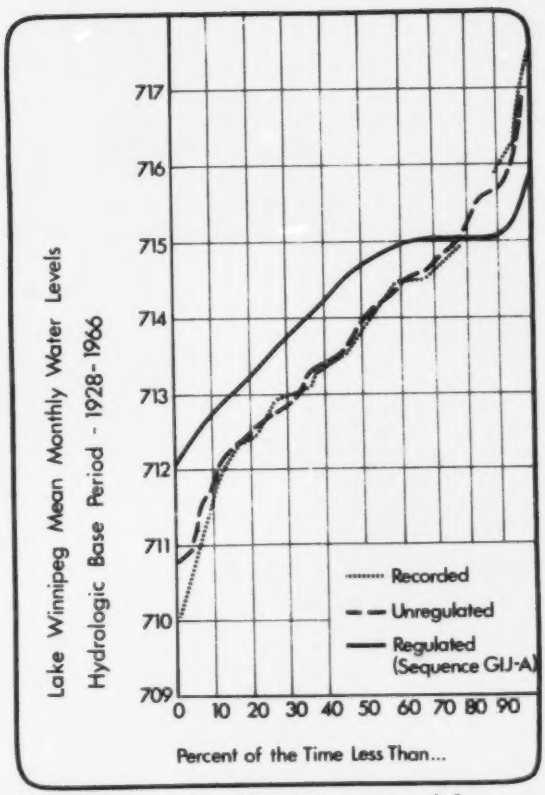


Figure 2-7 - Stage-duration curve - July -

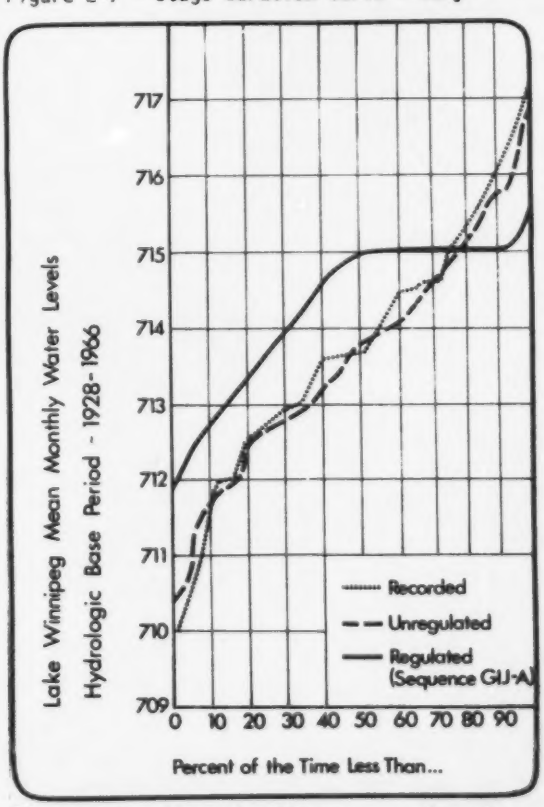


Figure 2-8 - Stage-duration curve - August -

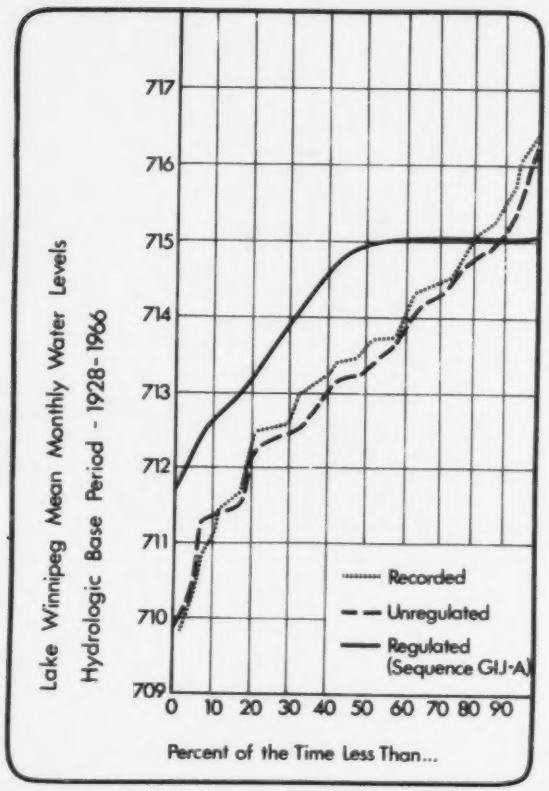


Figure 2-9 - Stage-duration curve - September -

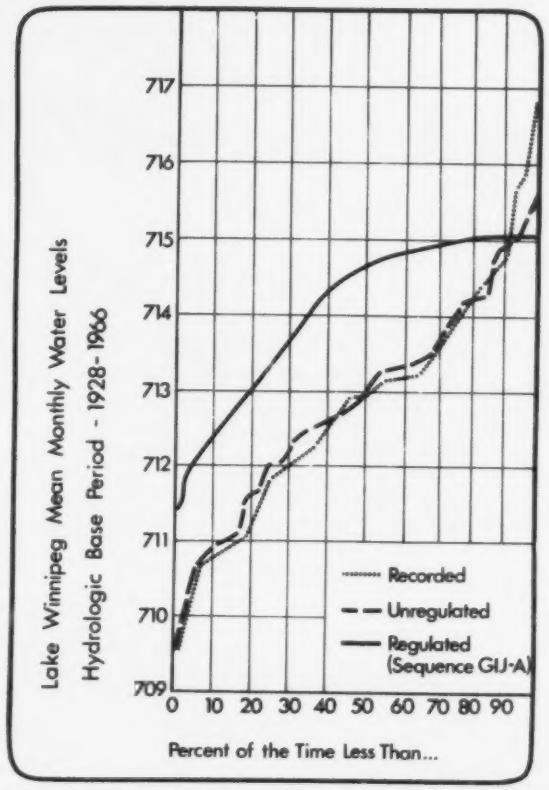


Figure 2-11 - Stage-duration curve - November -

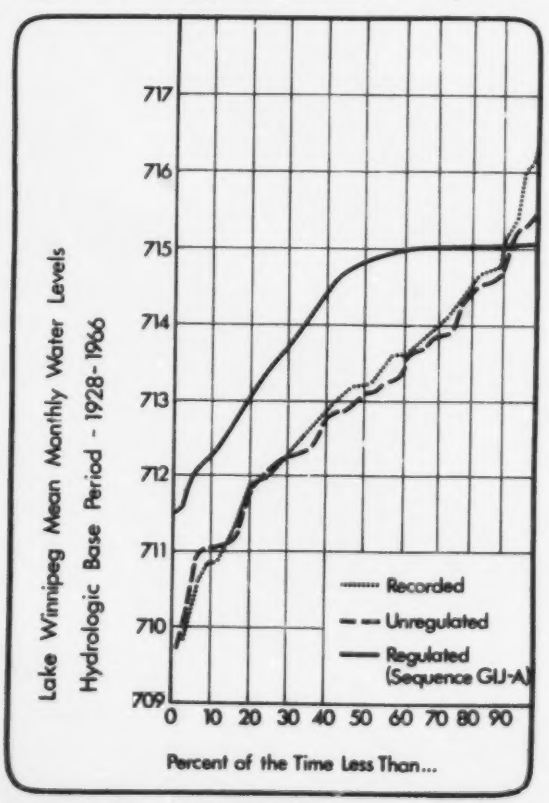


Figure 2-10 - Stage-duration curve - October -

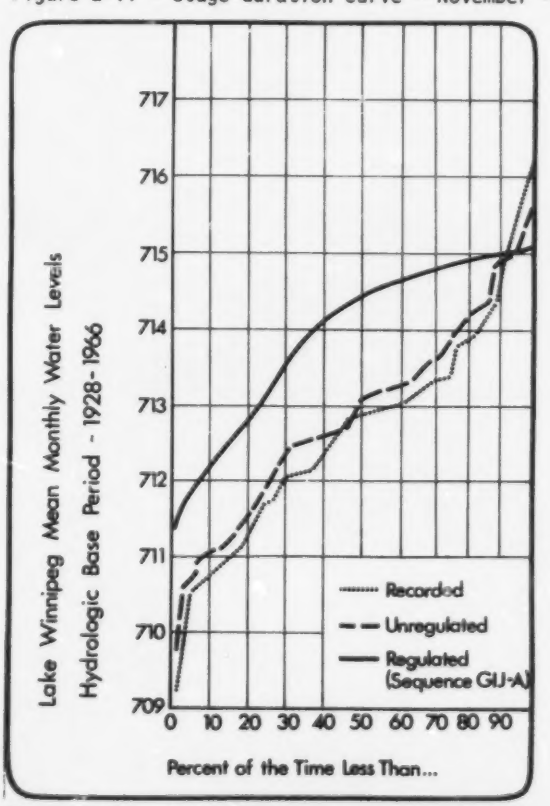


Figure 2-12 - Stage-duration curve - December -

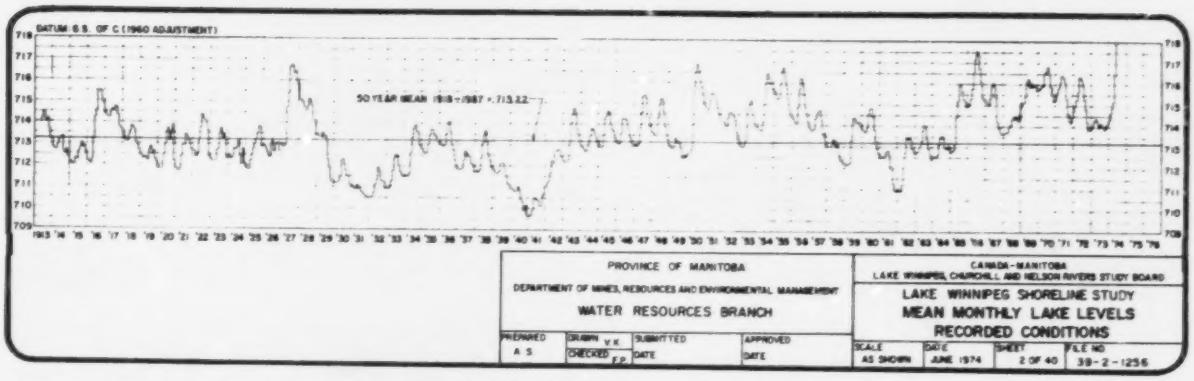


Figure 3 Mean Montly Lake Levels Recorded Conditions

5. DEFINITION OF EFFECTS OF REGULATION For purposes of this report, the effects attributable to regulation are defined to be the effects resulting from the difference between the "unregulated lake levels" and the "regulated lake levels". The anticipated actual effects are those arising from the difference between "recorded levels" and "regulated levels". Thus the effects attributable to regulation are not necessarily identical to the anticipated actual effects.

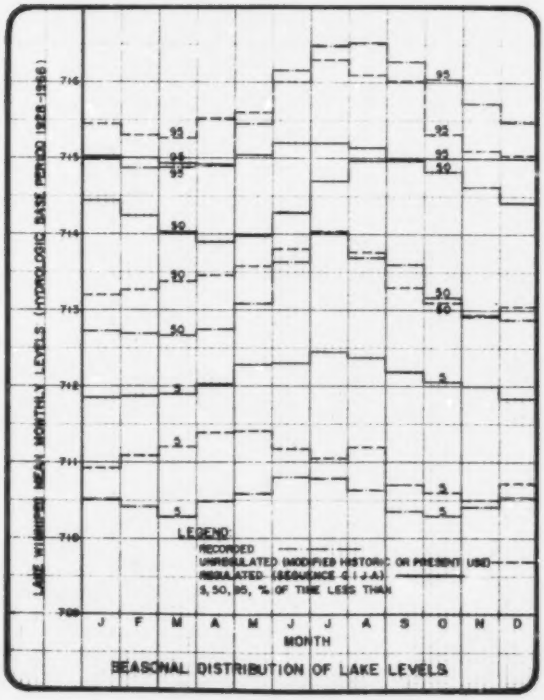

LAKE WINNIPEG MEAN MONTHLY LEVELS (HYDROLOGIC BASE PERIOD 1928-1966)
LEGEND
RECORDED
UNREGULATED (MODIFIED HISTORIC OR PRESENT USE)
REGULATED (SEQUENCE G I J A)
5, 50, 95, % OF TIME LESS THAN
J F M A M J J A S O N D
MONTH
SEASONAL DISTRIBUTION OF LAKE LEVELS

Figure 4 Seasonal Distribution of Lake Levels

Recorded erosion rates must however, be correlated with recorded levels rather than with unregulated levels.

The seasonal distribution of lake levels at the 95%, 50% and 5% of time less than levels under the three conditions as illustrated on Figure 4.

The seasonal distribution of levels at the 50% (but not at the 95% and 5%) time less than level may also be taken to represent approximately how the levels vary from one month to the next in a typical year.

CHAPTER 4

STUDY AREA

A. LOCATION

The study was confined to the southern portion of Lake Winnipeg - south of Riverton on the west shore and south of Elk Island on the east shore. This portion of the lake is approximately 42 miles long in the north-south direction and 16 to 26 miles wide in the east-west direction. The depth of water increases

from about 15 feet in the south to 40 feet in the north. A plan of the study area with surface and underwater contours is included as Figure 5.

B. ICE CONDITIONS

The lake is ice free from about May 8 to November 22. The time of spring breakup and the time of fall freeze-up may vary by about one week from the dates given. The ice processes and ice effects are dealt with in the section under the ice effects study.

C. LAKE LEVELS

The recorded levels of Lake Winnipeg are summarized in the following table from a period of record, 1913 to 1973.

TABLE 1
RECORDED LAKE LEVELS

Extreme Daily Low:	708.6 October 29, 1940
Extreme Daily High:	718.9 September 5, 1966
Extreme Instantaneous High:	719.8 September 5, 1966
Extreme Monthly Low:	709.6 February, 1941
Extreme Monthly High:	717.5 July, 1966
Long Term Mean:	713.2

In any year the monthly mean water level typically reaches a peak in July and then drops about one foot to a minimum in December. The annual mean level may change as much as two feet from one year to the next as a result of changes in inflow. A plot of recorded mean monthly levels is included as Figure 3, and the seasonal distribution of levels is shown on Figure 4.

The projected levels of the lake under regulated conditions are within the range of the recorded levels. In general, regulation of the lake will narrow the range of fluctuation by eliminating both extreme low and extreme high levels and will raise the mean open water level by about one foot. In addition, the water level would remain fairly constant from July to November instead of dropping about one foot as under recorded conditions. This is also illustrated on Figure 4.

When the wind blows over a body of water, the surface water will begin to move in the direction of the wind and will pile up against the windward shore. There will be a corresponding drop in level at the lee side of the lake. The height that the water is piled up, measured above the still water level, is referred to as wind setup. This phenomenon causes the level of the lake to fluctuate about the mean. The maximum recorded wind setup at Gimli is 3.78 feet and occurred on October 3, 1970. Setups of one foot are common. Typically, two or three days time is required for the level to change from a low to a high level. This is a reflection of the time required for the large volumes of water to flow from one end of the lake to the other. A seasonal bias has been observed in the wind setup, in that it is more severe in fall than in spring. More detailed wind setup statistics are presented in Annex 1.

When the surface of an enclosed body of water such as a lake is disturbed by changes in atmospheric pressure or winds, standing waves are sometimes set up which cause the water to rhythmically rise and fall at the shoreline.

Einarsson and Lowe (1965) (1) have studied this phenomena on Lake Winnipeg. Their findings indicate that in the south part, say Gimli to Victoria Beach, some 10 to 15 transverse disturbances per year may be expected. The amplitude (rise plus fall in water level) may be as high as 1.5 feet initially, and may decrease to zero over 10 to 12 oscillations, each oscillation

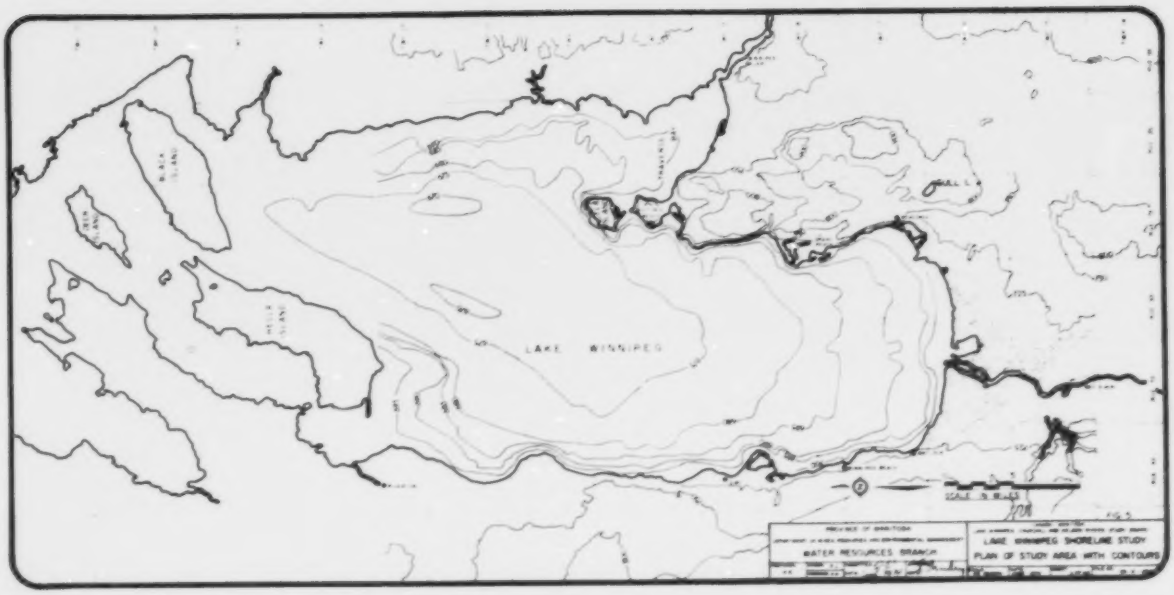


Figure 5 Plan of Study Area With Contours

having a period of about 1.7 hours. The effect of superimposing a seiche on a wind setup was also examined. In 24 case histories examined, the average increase in elevation of the peak seiche over a smoothed curve was 0.15 feet. In 24 cases, 21 showed a deviation of 0.1 feet or less while 3 cases showed larger deviations of 0.2, 0.3 and 0.5 feet. It was concluded that there was no indication that the prediction of wind setup could be improved by eliminating the effect of seiches. In summary, while the phenomena of seiches is of scientific interest, it is of no practical significance to the study of shoreline erosion and will not be considered.

D. WAVE ACTION

The results of wave measurements made as part of this study are summarized in the following table.

A seasonal bias has been observed in wave action. Wave action is more severe in fall than in spring. More detailed wave statistics are included in Appendix 2 of this report.

TABLE 2
SIGNIFICANT WAVE HEIGHTS ON SOUTH POOL OF LAKE WINNIPEG

% of Time Waves Are Greater Than Stated	Significant Wave Height	Wave Period
50%	1 foot	3 seconds
10%	3 feet	4 seconds
1%	6 feet	6 seconds

E. GEOLOGIC SETTING

Lake Winnipeg is a remnant of a much larger lake - glacial Lake Agassiz - formed by meltwater ponding against an ice barrier to the north. An understanding of the history of Lake Agassiz contributes to an understanding of present day shoreline processes of Lake Winnipeg. While the history of Lake Agassiz is not fully understood, there is agreement on the general sequence of events.

Some time prior to 12,500 years B.P. (before present) a major ice front from the northeast advanced approximately to

the present eastern shore of Lake Winnipeg. The ice advance deposited a till over most of the area it covered. Photograph 1 shows a typical till deposit on the east shore. As the ice front halted and then retreated, large quantities of sandy outwash material were deposited in the lake in front of the ice. Photograph 2 shows a large outwash sand deposit on Elk Island. The major deposits are the Belair Morraine extending from Elk Island in the north to Gull Lake in the south and the Milner Ridge some 20 miles further east. The outwash sands of the Belair Morraine are the main source of the beach sands along the eastern shore. In a number of locations the outwash sands have been deposited over lake clays. As the surface slopes of the outwash deposits have been steepened by erosion at present lake levels, the underlying clays have been overstressed and slope failures have occurred. Photograph 3 shows such a failure at the east side of Elk Island. A number of boulder rich till ridges mark the successive positions of the ice front. Some of these from off-shore reefs, southwest of Grand Marais and north of Grand Beach. Others form rocky headlands such as Grand Marais Point at Grand Beach, Ironwood Point west of Hillside Beach, and the north shore of Elk Island. Photograph 4 shows the rocky headland at Grand Beach. These bouldery ridges influence the shape of the shoreline.

Following the retreat of the ice margin to the northeast, ice advanced from the northwest to approximately the Belair ridge in the north and the Milner Ridge further south. Outwash sand and gravel deposits associated with this ice advance are much less extensive and more localized, the main deposits being in the Birds Hill Area. Hence there are only very minor amounts of sand available for beach building along the west shore. Numerous low boulder rich till ridges intersect the shoreline and influence

Photograph 1 Typical ice advance till deposit.

Photograph 2 Sand deposit on Elk Island.

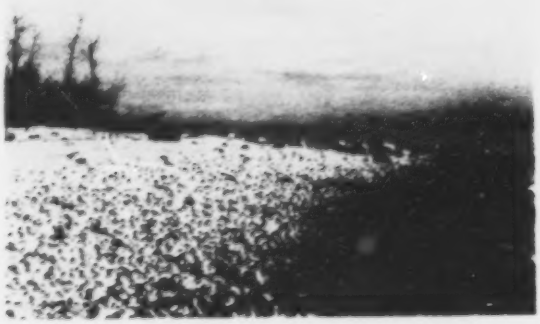
Photograph 3 Slope failure on Elk Island.

Photograph 4 Rocky headland at Grand Beach.

the shape of the shoreline because of their greater resistance to erosion. On the land side these ridges are overlain and masked by lacustrine deposits. However, along the beach they are revealed as boulder covered points of land. Photograph 5 shows such a ridge.

During the Lake Agassiz phase varying depths of clays and silts were deposited over the tills. These soils are free of stones, relatively unconsolidated and highly erodible. Photograph 6 shows such a clay shoreline. The differing rates of erosion along the west shore can be largely accounted for by the difference in erosion resistance between the bouldery till and the boulder free silts and clays.

While considerable work has been done in reconstructing Lake Agassiz water levels over the period from the formation of the lake (about 12,500 B.P.) to the time when the lake developed its present outlet (about 7500 B.P.) apparently no work has been done in reconstructing lake levels for the period from 7500 B.P. to the present. It has generally been assumed that the level of the lake has not changed significantly during this latter period. Inasmuch as the long term erosion rates are significantly influenced by a slow but long term rise or fall in lake level, it was considered useful to examine available evidence for long term changes in lake level. The results of this study suggest that due to isostatic rebound following removal of the ice sheet to the north, Lake Winnipeg has undergone and is now undergoing a tilting with the northern outlet rising relative to the southern end. A rise in the northern outlet causes an apparent rise in lake level at the southern end. Available evidence suggests that at the time when the present northern outlet developed (about 7500 B.P.) the lake basin was tilted with the present south end some 120 feet higher than the north end. As a result of this tilt, the southern shoreline was located in the vicinity of Berens River at the midpoint of the present lake. Since that time the lake level at the south end has risen and the shoreline advanced to its present position. The lake level at the south end has risen some 8 feet in the last 1000 years and is currently rising at the rate of about 0.4 feet per century. These rates may seem small. However, it will be pointed out later that such rates can account for substantial shoreline recession. Evidence for the preceeding discussion is presented in Annex 3.



Photograph 5 Till ridge masked by clay.

Photograph 6 Stove-free clay deposited during the Lake Agassiz phase.

F. SOILS ALONG THE SHORELINE

The soil profile along the west shore consists of a shallow depth (1 to 20 feet) of lacustrine clay underlain by clay till. Bedrock does not outcrop along the shore

profile. The lacustrine clay is stone free and highly erodible. The till contains significant quantities of sand, gravel and boulders. The quantity of coarse particles - sand, gravel and boulders - remaining after the fine grained particles have been washed away varies along the shore. Where till ridges outcrop along the shore, this quantity is sufficient to provide a continuous cover on the beach, and to retard or inhibit further erosion. The elevation of the land adjacent to the shoreline varies from 720 to 740. A geological profile of the west shore is included as Figure 6.

The elevation of land fronting on the south shore is at or near the lake level, except for an almost continuous sand dune which has developed behind the sand beach. The soils underlying the beach and sand dunes are lacustrine clays and silts. Some areas have extensive peat cover. A geological profile of the south shore is included as Figure 7.

The soils along the east shore are more variable and complex. These include glacial outwash deposits consisting mainly of sands, lacustrine clays and silts, and boulder rich

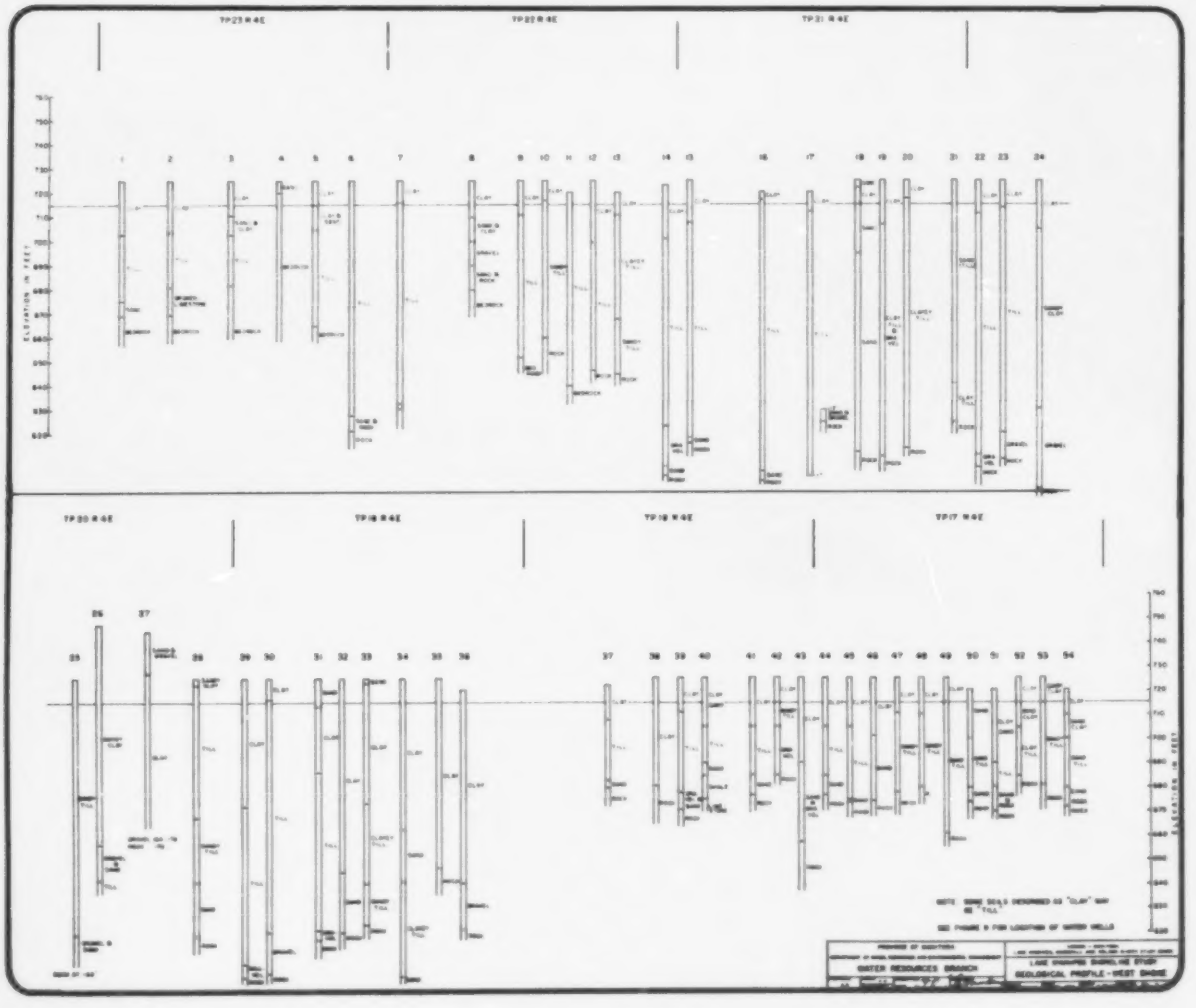


Figure 6 Geological Profile - West Shore

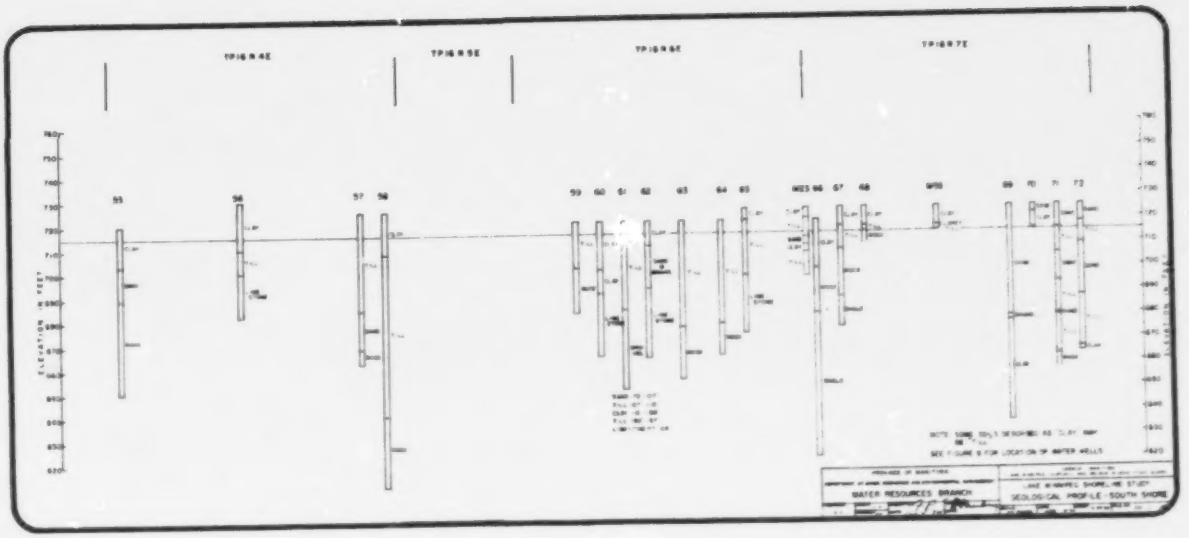


Figure 7 Geological Profile - South Shore

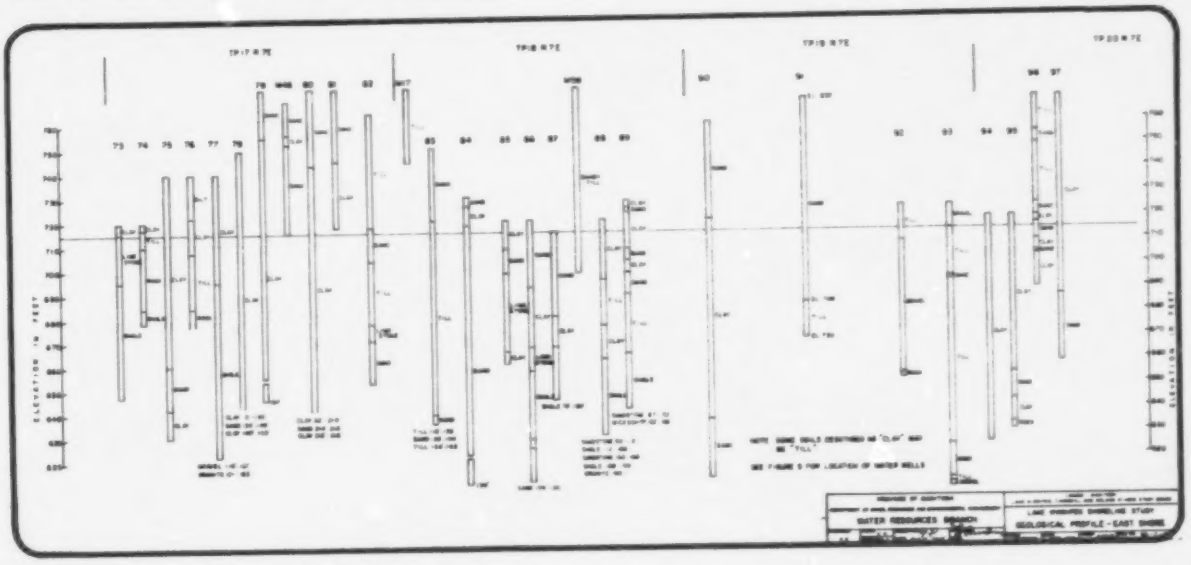


Figure 8 Geological Profile - East Shore

clay tills. Most of the headlands on the east side are clay tills armoured with large boulders. Only at the southwest corner of Elk Island does bedrock outcrop above the water level. The elevation of land fronting on the east shore varies from about 720 at the south to about 770 at Elk Island. A geological profile of the east shore is included as Figure 8. A description of surficial soils obtained from Agricultural soil survey maps is shown on Figure 9.

G. SHORELINE DEVELOPMENT

The land along the west shore has been developed for agriculture and cottages. The land along the south shore is largely undeveloped because it is subject to flooding, has virtually no backshore and has poor access. The land along the east shore is rapidly being developed for cottages. In 1971, there were about 6000 seasonal residences within 1 mile of Lake Winnipeg.

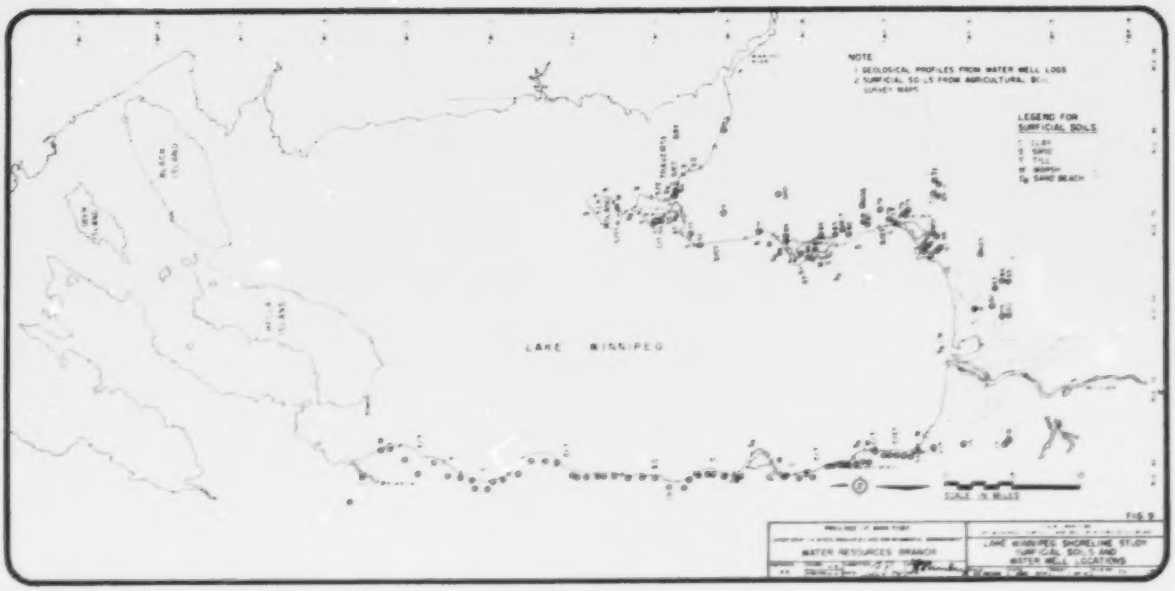


Figure 9. Surficial Soils and Water Well Locations.

of which 1200 fronted directly on the lake. The market value of these 6000 cottages was about $22.2 million. In addition, there were approximately 2000 resident and commercial properties with a market value of about $25.5 million within one mile of the shoreline.

CHAPTER 5

THE SHORELINE EROSION STUDY

A. DETERMINATION OF HISTORIC RATES OF SHORELINE RECESSION

Historic rates of shoreline recession were determined by plotting on a plan, the location of the shoreline as it existed at several different points in time. The average rate of recession at any site could then be computed for one or more increments of time.

A base plan to a scale of 1" = 200' was prepared by photogrammetry from aerial photography and horizontal ground control obtained in the fall of 1971. Vertical ground control was available from earlier surveys. The base plan showed the 1971 shoreline and contours to a distance of 3000 feet inland from the shoreline, the first line of cottages along the lake shore, all major buildings in sparsely settled areas, major roads, railroads and apparent property boundaries.

A second shoreline from the oldest available satisfactory aerial photographs was added to the base plan. The date of this shoreline varied from 1946 to 1967 for different reaches of the shoreline, depending on the availability of suitable photography. This second shoreline was located on the base plan photogrammetrically by superimposing features such as buildings or railroads which were common to the base plan and to this second set of photographs. In two areas of high rates of recession, several historic shorelines were derived from different sets of photography.

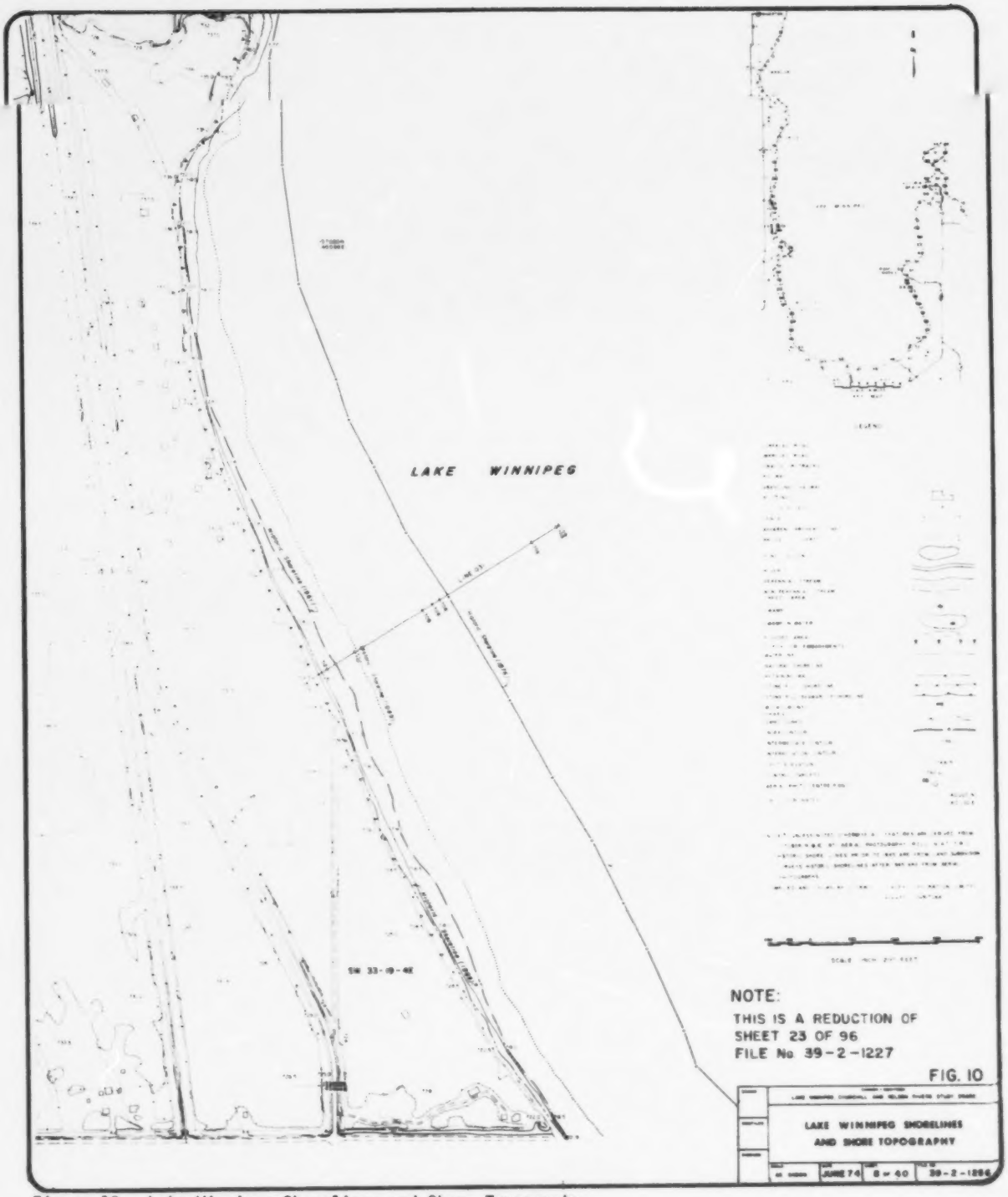


Figure 10 - Lake Winnipeg Shorelines and Shore Topography

A third shoreline was derived from land subdivision surveys dated 1874 to 1934. Most of these surveys included shoreline traverses. These earlier surveys were then related by calculation to surveys for railroads constructed along the east and west sides of the lake during the period 1902 to 1917. Plans showing the subdivision and railroad surveys were then prepared by

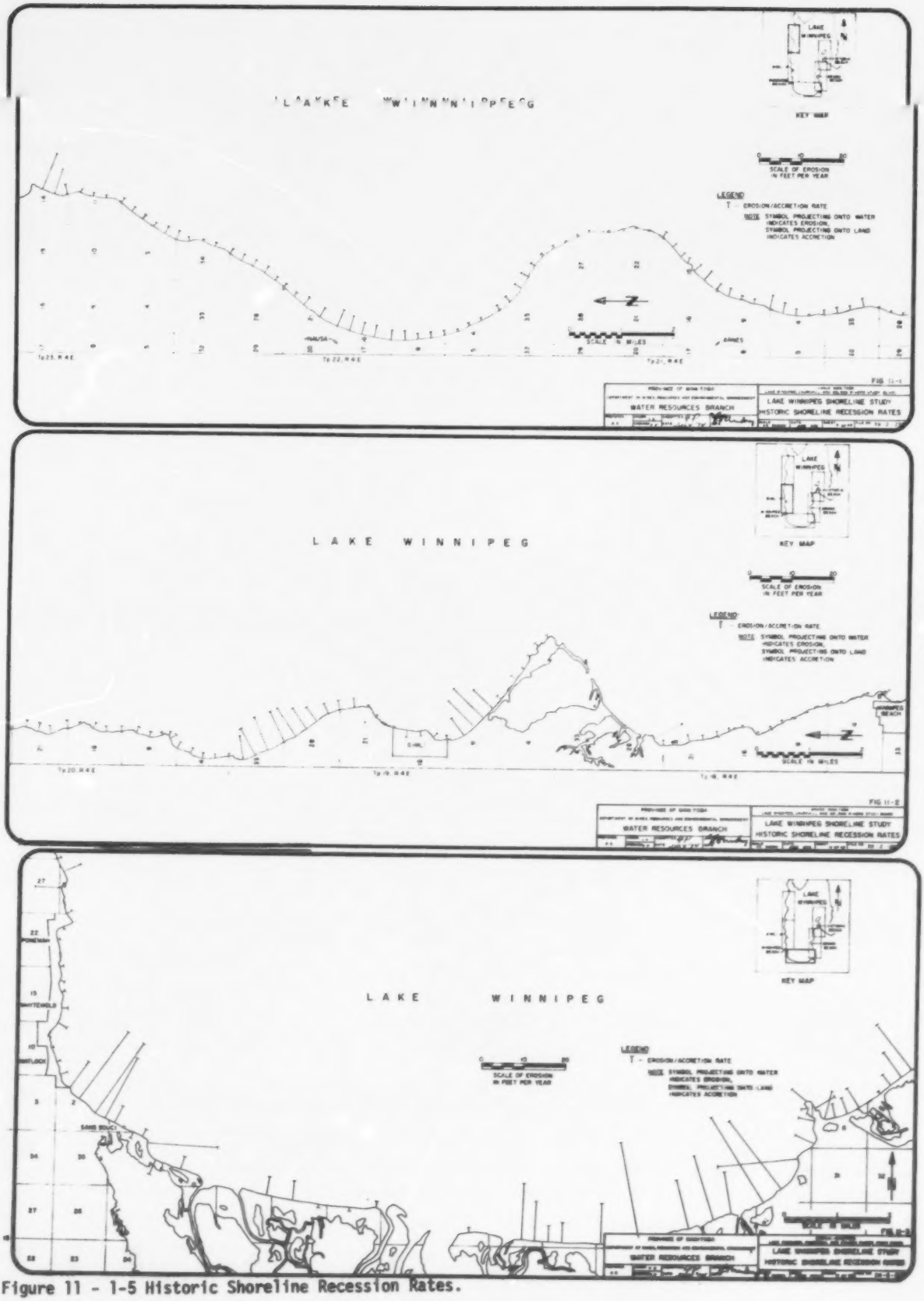

LAKE WINNIPEG
KEY MAP
SCALE OF EROSION IN FEET PER YEAR
LEGEND
T - EROSION/ACCRETION RATE
NOTE SYMBOL PROJECTING ONTO WATER INDICATES EROSION, SYMBOL PROJECTING ONTO LAND INDICATES ACCRETION
SCALE IN MILES
WATER RESOURCES BRANCH
LAKE WINNIPEG SHORELINE STUDY
HISTORIC SHORELINE RECESSION RATES
FIG 11-1
LAKE WINNIPEG
KEY MAP
SCALE OF EROSION IN FEET PER YEAR
LEGEND
T - EROSION/ACCRETION RATE
NOTE SYMBOL PROJECTING ONTO WATER INDICATES EROSION, SYMBOL PROJECTING ONTO LAND INDICATES ACCRETION
SCALE IN MILES
WATER RESOURCES BRANCH
LAKE WINNIPEG SHORELINE STUDY
HISTORIC SHORELINE RECESSION RATES
FIG 11-2
LAKE WINNIPEG
KEY MAP
SCALE OF EROSION IN FEET PER YEAR
LEGEND
T - EROSION/ACCRETION RATE
NOTE SYMBOL PROJECTING ONTO WATER INDICATES EROSION, SYMBOL PROJECTING ONTO LAND INDICATES ACCRETION
WATER RESOURCES BRANCH
LAKE WINNIPEG SHORELINE STUDY
HISTORIC SHORELINE RECESSION RATES

Figure 11 - 1-5 Historic Shoreline Recession Rates.

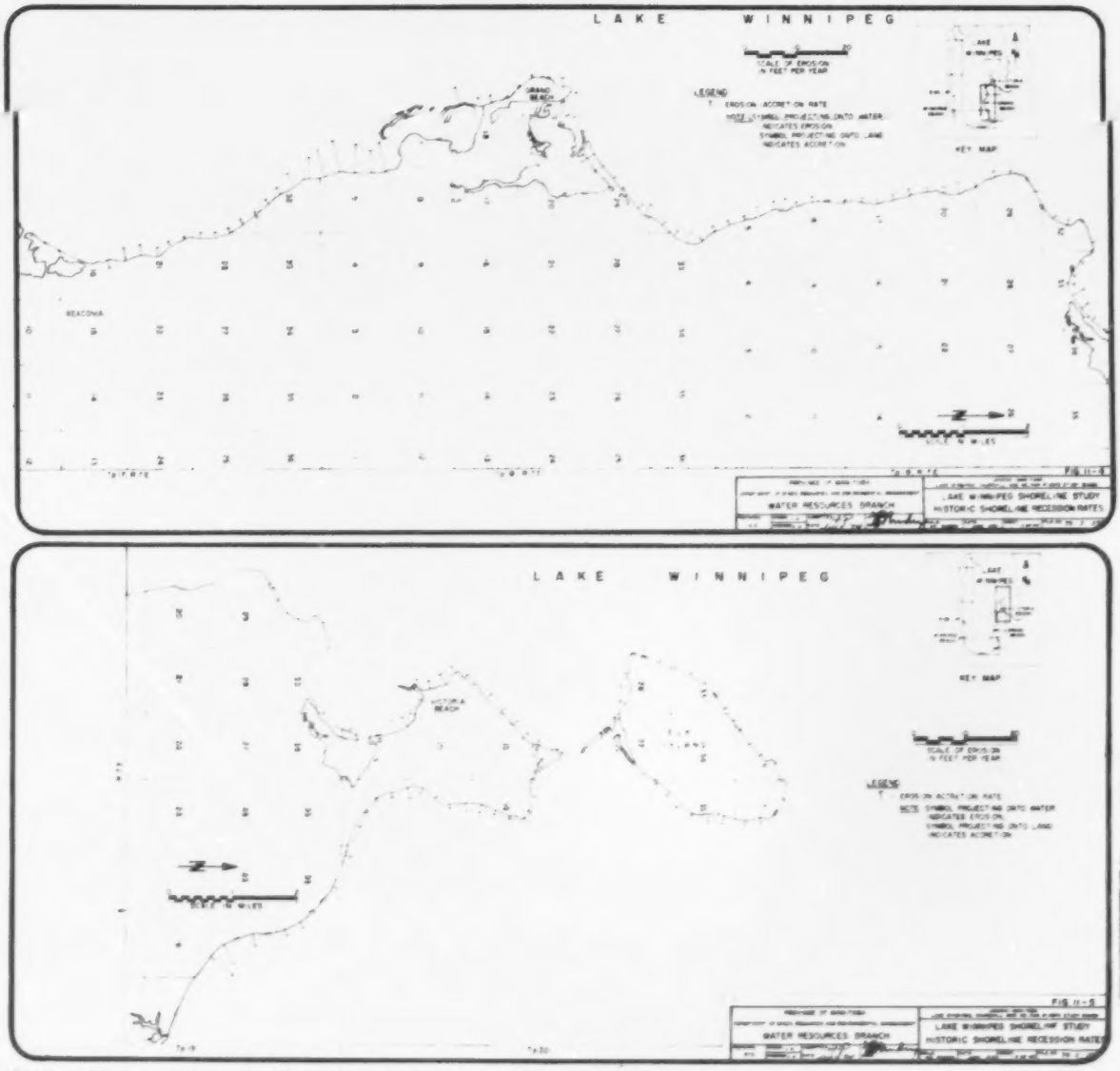


Figure 11-1-5 Historic Shoreline Recession Rates Continued

computer-plotter to the same scale (1" = 200') as the plans prepared by photogrammetry. The shoreline from the subdivision survey was then superimposed on the plans prepared by photogrammetry by matching the railroads which appeared on both sets of plans. Because of the absence of a common recognizable feature at the south end of the lake, it was necessary to "bridge" from the railroad on the east side to the railroad on the west side. The positions of the corners of the land survey sections were computed in terms of the co-ordinate system used for the photogrammetric work to permit the correct plotting of the land survey shoreline. On Elk Island the original subdivision survey monuments were located and targeted to appear on the aerial photographs so that the two surveys could be related.

A typical example of a shoreline and shore topography plan is included as Figure 10. Copies of full size plans are available

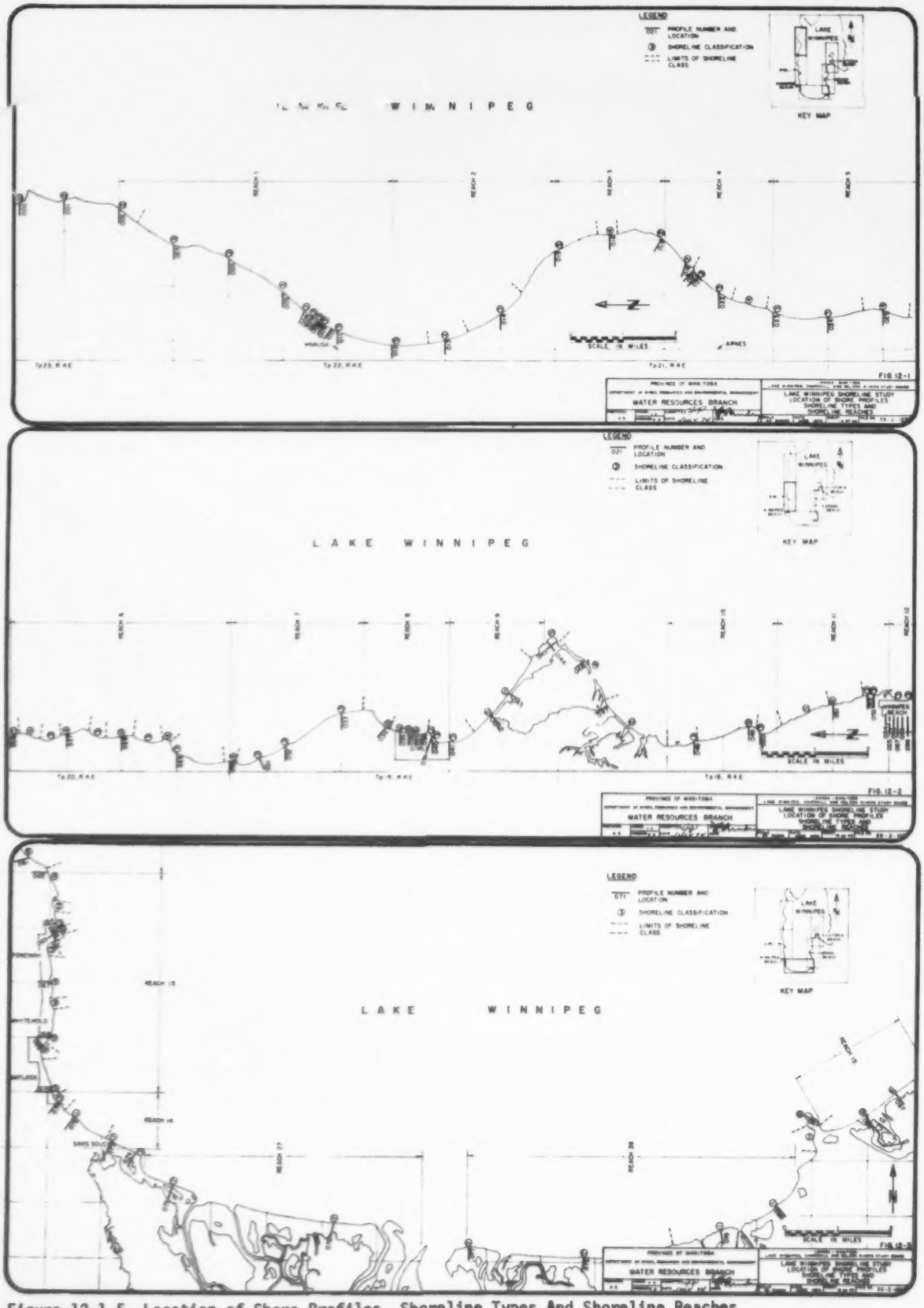


Figure 12-1-5 Location of Shore Profiles, Shoreline Types And Shoreline Reaches

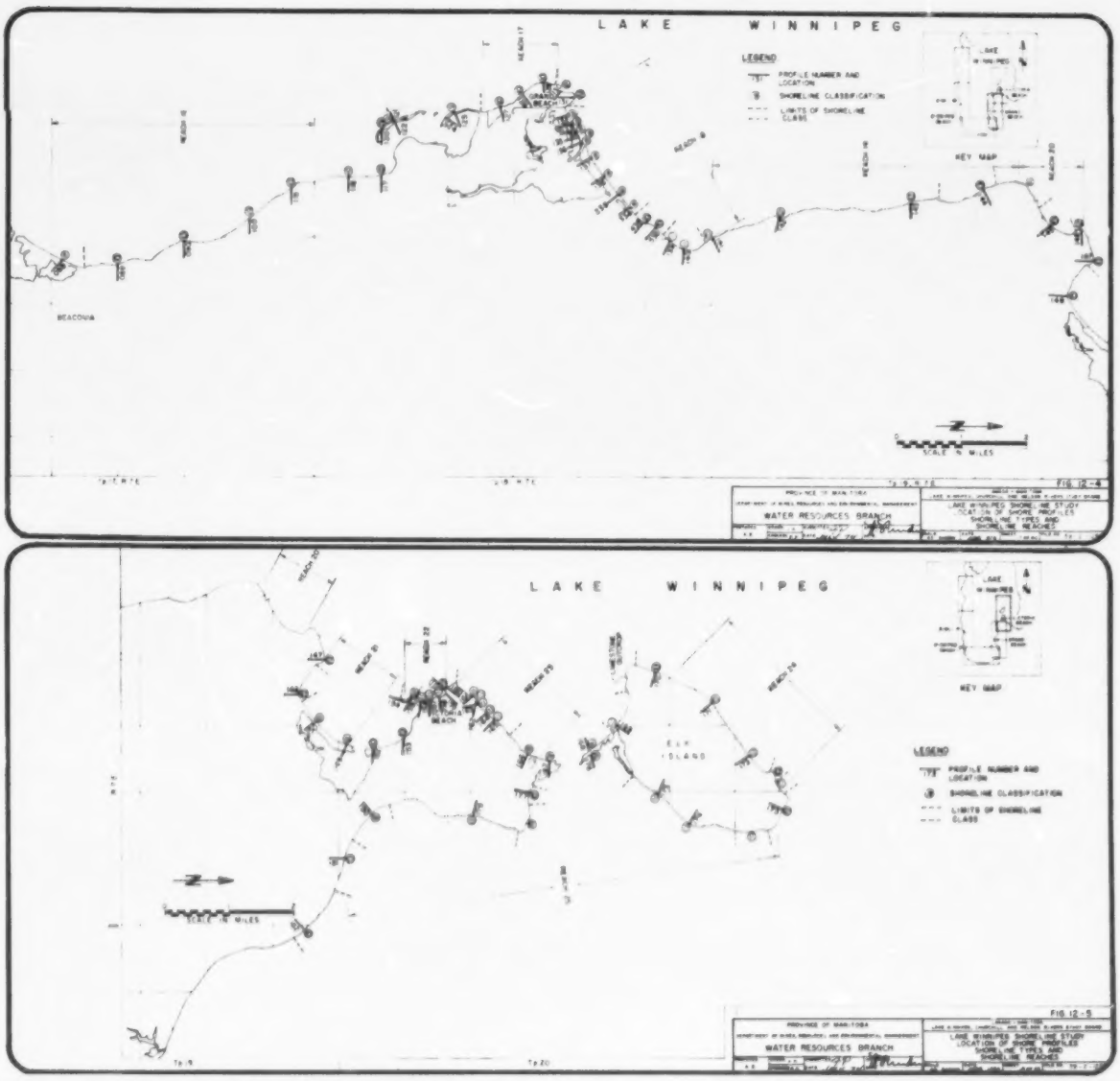


Figure 12 - 1-5 Location of Shore Profiles, Shoreline Types And Shoreline Reaches Continued.

from the Surveys, Mapping and Lands Branch, Department of Mines, Resources and Environmental Management, Province of Manitoba. The historic rates of shoreline recession in terms of feet per year are summarized on Figures 11-1 to 11-5.

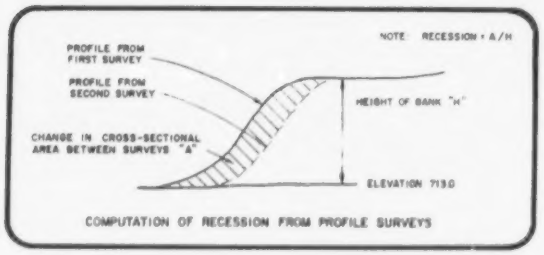
The location of the shoreline at the south end of the lake is very sensitive to the lake level. The line of vegetation will advance and recede in response to changes in a two or three year mean lake level. It is likely that the recession computed in this area is largely attributable to higher lake levels in 1969-1971 than in 1930-1934.

B. DETERMINATION OF CURRENT RATE OF SHORELINE RECESSION

During the course of the study some 150 shoreline profiles were established and referenced around the perimeter of the lake. These profiles were established at intervals of approximately one mile. The profiles were

spaced more closely at beaches and intensively developed areas and more widely along sparsely settled and less valuable shoreline land. The locations of the profiles are shown on Figures 12-1 to 12-5. These profiles were surveyed down to approximately elevation 713 by level and tape from 1 to 3 times per year to provide short term recession rates to correlate with lake levels and wave action.

The survey data was transferred to punch cards and the amount of recession between successive surveys at each profile was calculated by computer as shown in the following sketch:


NOTE: RECESSION = A/H
PROFILE FROM FIRST SURVEY
PROFILE FROM SECOND SURVEY
CHANGE IN CROSS-SECTIONAL AREA BETWEEN SURVEYS "A"
HEIGHT OF BANK "H"
ELEVATION 713.0
COMPUTATION OF RECESSION FROM PROFILE SURVEYS

This method of computing shoreline recession is considered to yield a more reliable rate than a change in the horizontal position of the top of the bank. In some cases the position of the top of the bank is not well defined. In other cases, the erosion process undercuts the bank, with the result that the top of the bank recedes in a series of steps as blocks of earth collapse. In this case, the recession of the top of the bank does not correlate with the erosion taking place at the base of the bank over the short term. The base elevation of 713 was selected as the lowest elevation which could consistently be surveyed by the level and tape method.

These profiles were also plotted by computer plotter to permit the profiles to be examined visually for errors and to detect situations where the method of analysis did not apply.

An example of plotted successive profiles is included as Figure 13. All the available shoreline recession data, both short term and long term, was plotted on a graph showing the location of the shoreline at various points in time. An example of such a graph is included as Figure 14.

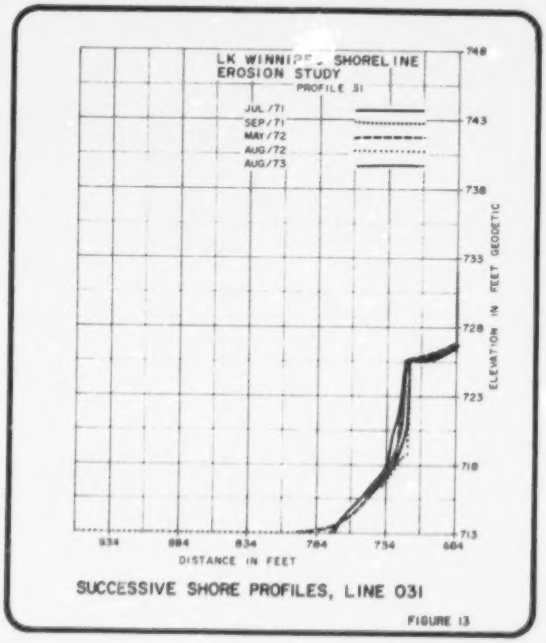


Figure 13 Successive Shore Profiles, Line 031

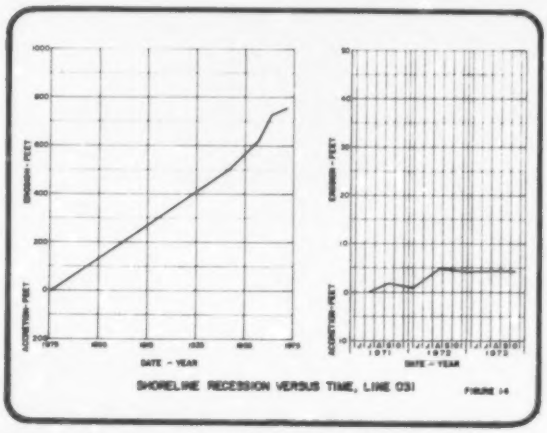


Figure 14 Shoreline Recession Versus Time, Line 031

C. MEASUREMENT OF OFFSHORE TOPOGRAPHIC PROFILES

Analysis of the effects of waves on the shoreline requires a knowledge of the underwater topography near the shoreline. For this reason, the shore profiles referred to earlier were surveyed to a distance of 2000 feet offshore. Some profiles were surveyed only once, while others were surveyed a number of times. The survey was made with a Raytheon Precision Survey Fathometer Model DE 719 mounted in a 20 foot boat. The boat was pulled toward the shore at a constant speed of 200 feet per minute by a small gasoline engine powered winch mounted in the boat with a steel cable anchored to the shore. The fathometer recorder chart speed was 4 inches per minute so that the resulting horizontal scale was 50 feet per inch. The vertical scale was approximately 5 feet per inch. Because the speed of the winch motor varied slightly during any run, the horizontal scale was checked and adjusted by "fix marks" on the chart corresponding to measured marks on the winch cable. The fathometer profile overlapped the level and tape profile to produce a continuous bank and offshore profile. The fathometer profile was digitized by visually picking off co-ordinates off the chart. These co-ordinates were then combined with the level and tape co-ordinates and plotted by computer to provide a continuous bank and offshore profile as shown in Figure 15.

D. DETERMINATION OF SOIL PROFILES

To determine the quantity and distribution of sand along the shoreline, the soil profile along most profiles was surveyed. The offshore profile was surveyed in winter under ice conditions. Holes were drilled in the ice at distances of approximately 200, 300, 400, 500, 600, 700, 800, 1000, 1200, 1600 and 2000 feet from the shoreline. Three inch diameter Shelby tubes 3 feet to 5 feet long were driven into the lake bottom. In many cases the tubes penetrated through a sand layer into underlying clay. In these cases the clay formed a plug in the

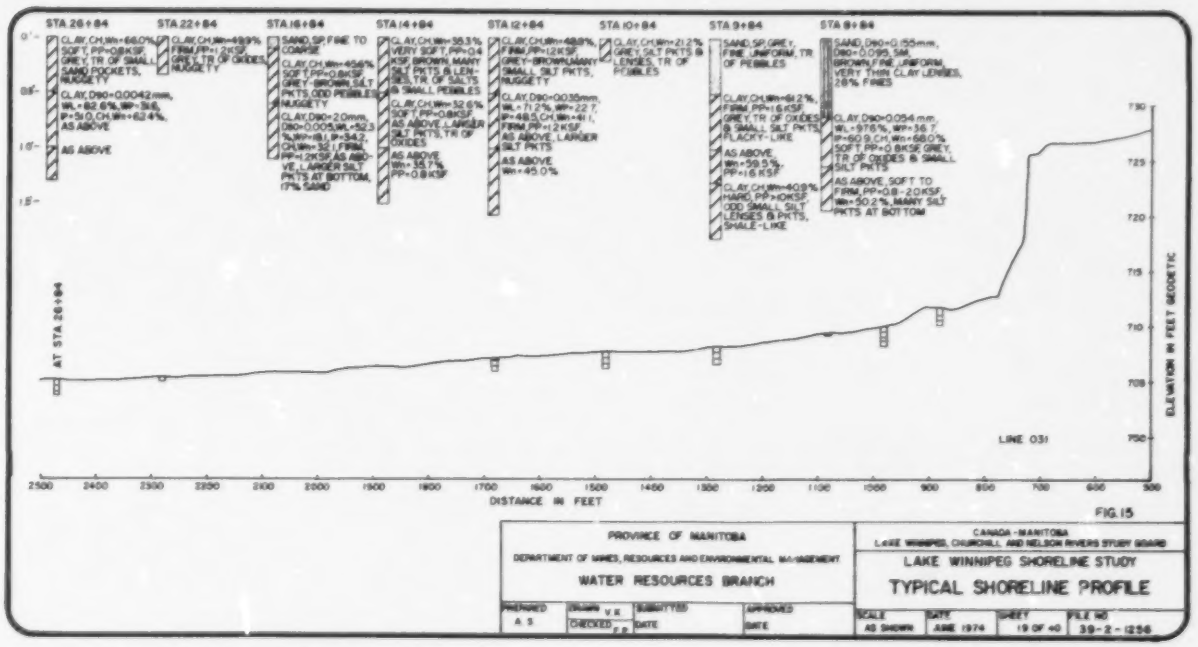


FIG.15

Figure 15. Typical Shoreline Profile, Line 031.

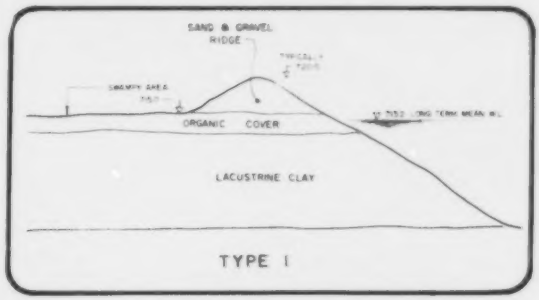
bottom of the tube to retain the overlying sand and the depth of the sand and the characteristics of the sand and clay could be determined from the recovered samples. Where the depth of the sand exceeded the length of the tube, occasional difficulty was encountered in retaining the sand sample. These difficulties were largely overcome by use of a piston sampler or by overdriving the tube. Where the depth of sand exceeded the length of the tube, the depth of sand was determined by sounding with a water jet pipe. The pipe penetrated the sand easily, but stopped short when the underlying clay was encountered. The soil profile above the water level was surveyed in the summer time by visually examining the bank. The soil profile together with lab test results on the soil samples were plotted on the shoreline profiles as illustrated on Figure 15. Copies of the other profiles are available from the Water Resources Branch of the Department of Mines, Resources and Environmental Management.

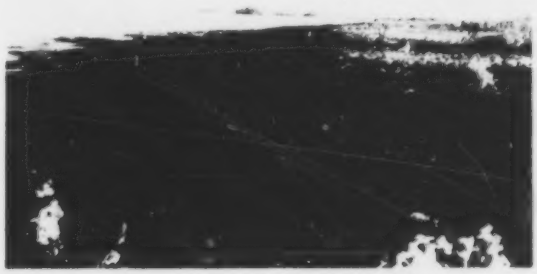
E. MAPPING OF SHORELINE TYPES

The shoreline within the study area was mapped by field inspection and interpretation of aerial photographs. The land areas surrounding the study area may be subdivided into three distinct characteristic groups: lacustrine clays underlain by till along the west shore; wind and water sorted granular deposits along the south shore and at a number of locations on the east shore; and sandy boulder tills along most of the east shoreline. The three groups were further subdivided into twelve types of shorelines. The location of each shoreline type is summarized on Figures 12-1 to 12-5.

The following are brief descriptions of each shoreline type used in classifying the shoreline within the study area.

Type 1. The insitu soil in the bank consists of an organic cover of approximately one foot, underlain by a lacustrine clay. The backshore is generally marsh and lower than 718.0 with a ridge of sand and gravel deposited by wave action. The beach slope is stripped of granular material cover. This type of shoreline is found in an area of strong littoral drift and no littoral drift barriers. This shoreline occurs in the southwestern and southeastern portions of the lake. A typical erosion rate is 10 to 15 feet per year and the erosion threshold as defined on page 54 is typically at elevation 711.0. A sketch and photograph are shown below.

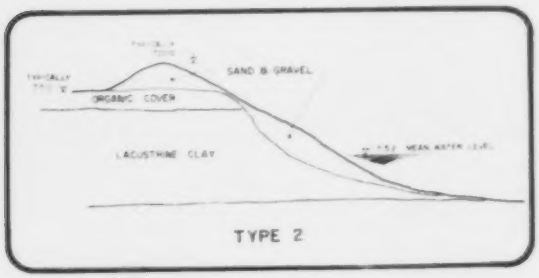




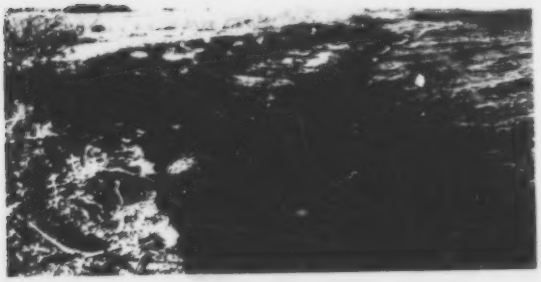
Photograph 7

Type 2. The insitu bank material is lacustrine clay with an organic cover approximately one foot thick.

The backshore is generally marsh and the land elevation is lower than 718.0. A ridge consisting of a mixture of sand and gravel deposited by wave action is present at the shore. Additionally, this type of shoreline has a cover of sand and gravel on the beach slope approximately 1 1/2 feet thick. The typical erosion rate is four feet per year and the typical erosion threshold is at elevation 712.0. A sketch and photograph are shown below. Types 2, 3 and 4 constitute most of the west shore of the lake.



TYPE 2

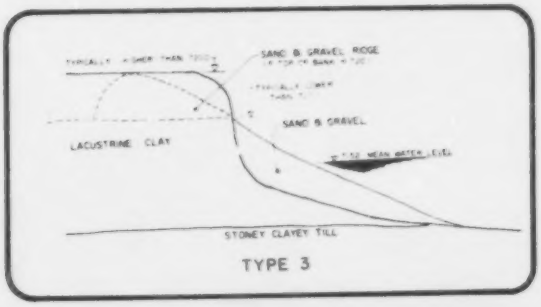


Photograph 8

Type 3. The insitu bank material is lacustrine clay over stoney clay till. The top of the bank is normally at elevation 720.0 or higher. Where the top of the bank is lower than 720.0 a ridge of sand and gravel is deposited on top of the bank by wave action.

The granular material on the beach slope consists of a mixture of sand and gravel with a trace of cobbles and the odd boulder. Thickness of the granular material is normally 1 1/2 feet.

The typical erosion rate is one to three feet per year although rates up to 8 feet per year have been observed and the typical erosion threshold is at elevation 712.0. A sketch and photograph are shown below. This is the predominant shoreline type on the west shore.



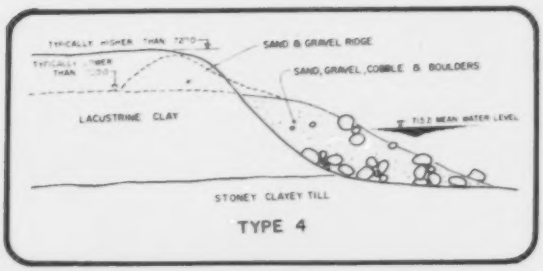
TYPE 3

Photograph 9

Type 4. The insitu bank material is lacustrine clay over stoney clay till. Generally the top of the bank is higher than elevation 720.0, however, if the top of the bank is lower than elevation, a ridge of gravel and sand is deposited by wave action.

The granular material on the beach slope consists of sand, gravel, cobbles and boulders. The quantity of sand and gravel is greater than the quantity of cobbles and boulders. Generally the maximum depth of granular material is two to three feet on the beach slope.

The typical erosion rate is 1 to 3 feet per year and the typical erosion threshold is at elevation 713.0. A sketch and photograph are shown below. This type occurs at several locations along the west shore.



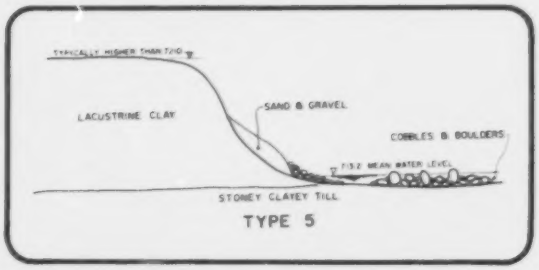
TYPE 4

Photograph 10

Type 5. The insitu bank material is lacustrine clay over stoney clay till and the top of the bank is higher than elevation 720.0.

The beach material consists of sand, gravel, cobbles and boulders, however, there is only a small quantity of sand and gravel. Generally, the beach slope is paved with cobbles and boulders with a small wedge of sand and gravel located at the bank face.

The typical erosion rate is 0 to 3 feet per year and the erosion threshold is approximately at elevation 713.0. A sketch and photograph are shown below. This type occurs at several locations along the west shore.



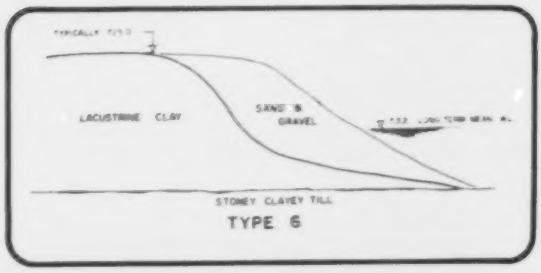
TYPE 5

Photograph 11

Type 6. The insitu bank material is lacustrine clay over stoney clay till and the top of the bank is generally higher than elevation 720.0.

The granular beach material consists of sand and gravel in sufficient quantity to prevent erosion. The depth of the sand and gravel is approximately ten feet. This type of shoreline occurs in an area of accretion. It is found only at Gimli and Winnipeg Beach.

The erosion rate is zero feet per year and the erosion threshold is approximately at elevation 713.0. A sketch and photograph are shown below.



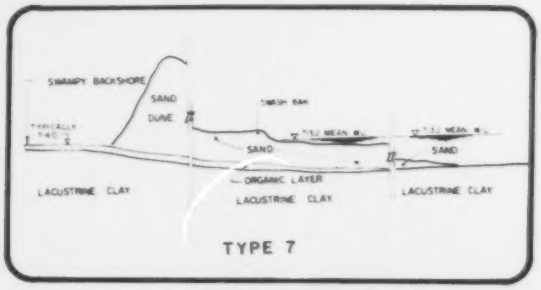
TYPE 6

Photograph 12

Type 7. The insitu shoreline soil consists of lacustrine clay under an organic cover and wind and water sorted sand dunes over the organic material. The backshore is generally a marsh area.

The granular beach material is a wind and water deposited sand with the depth of sand at the water line being approximately ten feet.

The typical computed recession rate is approximately ten feet per year although it is believed that the change in the location of the shoreline is largely a reflection of a change in lake level. The erosion threshold is at elevation 712.0. This type occurs only along the south shore of the lake. A sketch and photograph are shown below.



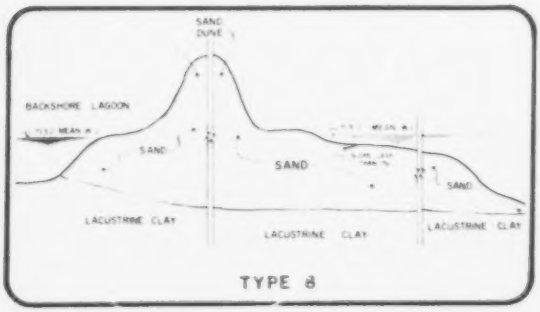
TYPE 7

Photograph 13

Type 8. The insitu shoreline soils consist of wind and water deposited sand over lacustrine clay. The sand dunes are variable both in height and width. A lake lagoon is present behind the dunes.

The granular material on the beach is sand with the depth of deposit being 10 to 15 feet at the waterline.

The typical erosion rate is 0 to 3 feet per year and the erosion threshold is approximately at elevation 713.0. This type is found only at Patricia Beach, Grand Beach and Hillside Beach.



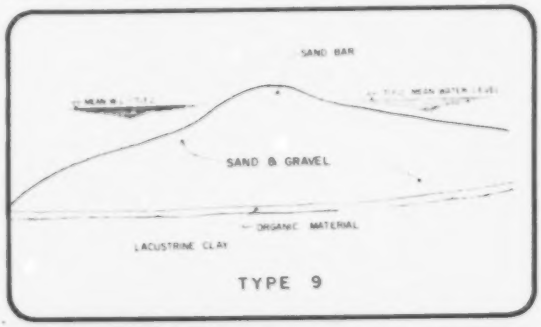
TYPE 8

Photograph 14

Type 9. The soil is a water deposited sand from lake processes. These are generally called sand spits and sand bars and vary considerably in size. This type is found south of Willow Island on the west shore, and south of Grand Marais, and between Elk Island and Victoria Beach on the east shore.

The beach material is sand with depths generally approximately 15 feet deep.

The erosion rate is variable and in many instances accretion is occurring. The erosion threshold is approximately at elevation 713.0. A sketch and photograph are shown below.

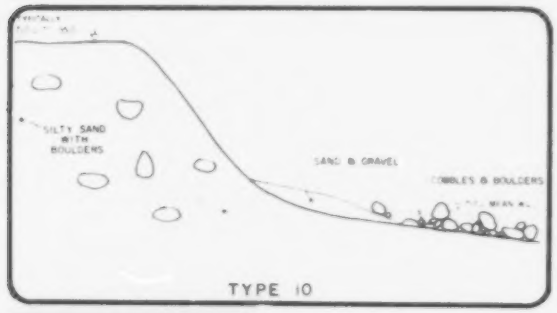


TYPE 9

Photograph 15

Type 10. The insitu bank material consists of silty sand with boulders with the top of the bank typically higher than elevation 720.0. The beach slope has some sand and gravel (approximately 1 to 2 feet) with a considerable coverage of boulders and cobbles.

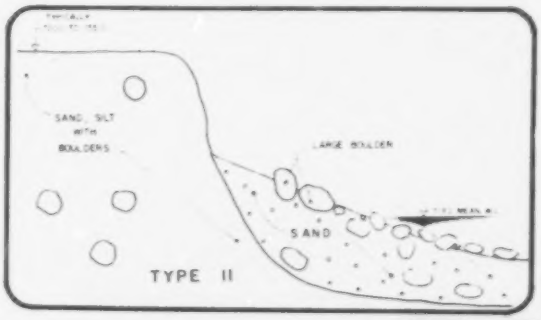
The erosion rate is generally two to four feet per year and the erosion threshold is at elevation 713.0. Types 10, 11 and 12 constitute most of the east shore of the lake.



Photograph 16

Type 11. This is the predominant shoreline type at Victoria Beach and Elk Island. The insitu bank material consists of sandy silt with boulders with the top of the bank higher then elevation 720.0. The beach material consists of a mixture of sand, gravel, cobbles and boulders, however, sand and gravel is more predominant. The depth of sand and gravel at the waterline varies from a few feet and may be up to thirty feet.

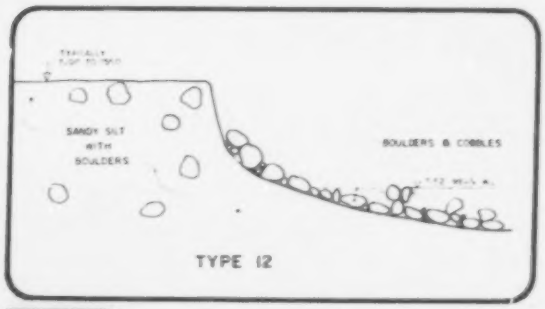
The typical erosion rate is 0 to 3 feet per year and the erosion threshold is at elevation 713.0. A sketch and photograph are shown below.



Photograph 17

Type 12. This type is found at several headlands along the east shore. The insitu bank material consists of sandy silt with boulders. The top of the bank is typically higher than elevation 720.0. The beach material is composed of cobbles and boulders to the extent the erosion is stopped.

The erosion rate is zero feet per year and the erosion threshold is at elevation 714.0 or higher. A sketch and photograph are shown below.



Photograph 18

F. MEASUREMENTS OF WINDS, WAVE CLIMATE AND WATER LEVELS

1. WINDS: Wind data was required to generate by correlation missing wave data. Since the wave measuring equipment did not measure the direction of the approach of the waves, the wind direction was also used to establish the wave direction.

The Ministry of Transport has operated an anemometer at the Gimli aerodrome 2 1/2 miles west of the shoreline from 1941 to the winter of 1971-72. In the winter of 1971-72, the anemometer was relocated to within 500 feet of the shoreline. During the open water season of 1972 and 1973, an additional anemometer was operated at Grand Beach. The locations of the anemometers are shown on Figure 16. Wind velocities in m.p.h. were tabulated for one hour intervals and introduced into a data bank. The mean wind velocity at 0 hours, (averaging the 2300 hour, 0 hour, and 0100 hour wind speeds) at 0300 hours, (averaging the 0200 hour, 0300 and 0400 hour wind speeds) etc., were computer calculated to represent the wind velocities at the 3 hour intervals (0 hours, 0300 hours, 0600 hours, etc.). Wind directions were tabulated for 16 compass points in the case of Gimli and 8 compass points in the case of Grand Beach. For purpose of this report the relocation of the anemometer at Gimli was assumed to have no effect on the observations.

It should be noted that the winds recorded by shore based anemometers are not necessarily the same as winds acting on the water surface to generate waves. The ratio of the overwater wind speed to the overland wind speed has been determined to be a function of the following variables:

(a) Atmospheric stability as measured by the air-water temperature difference.
(b) Wind speed.

(c) Overwater fetch distance.
(d) Location of the land station relative to the shoreline (i.e. distance from shoreline, upwind or downwind from lake).

Additionally, the wind velocity observed at any one point depends on the altitude of the anemometer above the ground or water.

2. WAVES During the course of the study the wave climate was measured as follows:

WAVE CLIMATE MEASUREMENTS

	Period of Record		
Instrument Site	1971	1972	1973
1 1/2 mile E of Gimli	15 Sept.-7 Nov.	10 June-23 Oct.	
1.0 mile N. of Grand Marais	22 June-10 Nov.	18 May-23 Oct.	20 May-5 June

Measurements were made with Data Well "Waverider" accelerometer buoys moored in a 30 feet depth of water and transmitted to shore-based recorders. The system was programmed to record for 20 minute periods at intervals of 3 hours. Each recording was analysed to produce a wave spectrum for this recording interval.

The Wave Climate Study Group of the Marine Engineering Division of the Ministry of Public Works of Canada supplied the equipment for this study and also performed the data analysis and presentation. A description of wave theory and detailed wave statistics are included in Annex 2. The equivalent wave height and peak period for each recording interval were introduced into a data bank. The direction of the waves was assumed to be the same as the direction of the winds at the time of recording.

3. WATER LEVELS. Water levels are recorded continuously at Gimli, Victoria Beach, Berens River and at a number of other sites on Lake Winnipeg by the Water Survey of Canada. In addition, the Canada Ministry of Public Works Dredge 201 records water levels at the mouth of the Red River on an hourly basis during the dredging season. In addition to the above, a water level recorder was installed at the mouth of the Red River and operated during the period August to October, 1972 and May to October, 1973. The recorder at the south end of the lake (at the mouth of the Red River) was installed to determine how the wind setup varied over the southern portion of the lake. A more detailed discussion of wind setup and wind setup statistics is included in Annex 1. The instantaneous water level (the wave effect being eliminated) and the wind effect eliminated lake level at Gimli at 3 hour intervals of time were introduced in the data bank.

4. WAVE AND WIND SETUP BASE PERIOD OF RECORD. It is likely that winds and the resultant waves and wind setup vary seasonally. Mean monthly water levels also vary seasonally. The description of the wave and instantaneous water level climate which causes erosion requires the combining of waves, wind setup and mean monthly water levels. Waves and mean monthly water levels vary independently of each other and can be combined statistically simply. However, waves and wind setup are both wind generated. As a result, one might expect to find a coupling between waves and wind setup. For example, in the south basin of the lake one would expect a north wind to generate waves travelling south and an increase in water level due to setup, while a south wind would produce waves travelling north and a decrease in water levels. In the south basin, one might expect waves travelling south to be associated with increased water levels, and waves travelling north to be associated with decreased water levels.

For purposes of the calculations, a standard wave and wind setup climate base period of record was developed. A sequence of wave, wind, and wind setup data sets was compiled on punch cards for 3 hour increments of time for the period May 15 to November 15 for years 1971, 1972, 1973 for both Gimli and Grand Beach. Some internal correlations were required to supply some data missing in some sets. Each card included the following data:

- Year, Month, Day, Hour

Gimli

- Instantaneous recorded water level (wave effect eliminated)
- Wind effect eliminated water levels
- Wind velocity m.p.h.
- Wind direction
- Equivalent wave height
- Wave energy carried forward (20 H^2T)
- Wave period.

Grand Beach

- Wind velocity
- Wind direction
- Equivalent wave height
- Wave energy carried forward (20 H^2T)
- Wave period

It was assumed that the wave and wind setup climate recorded during this 3 year period adequately represented the wave and wind setup climate in any past or future 3 year period. The mean monthly water levels were considered to vary independently of the wave and wind setup climate.

5. GENERATION OF MISSING DATA. Except for some minor gaps, data were available for the following periods.

AVAILABILITY OF DATA

	Winds		Waves		Water Levels
Year	Gimli	Grand Beach	Gimli	Grand Beach	Gimli
1971	15 May - 15 Nov.		15 Sept. - 7 Nov.	22 June - 10 Nov.	15 May - 15 Nov.
1972	15 May - 15 Nov.	15 May - 15 Nov.	10 June - 22 Oct.	18 May - 23 Oct.	15 May - 15 Nov.
1973	15 May - 15 Nov.	15 May - 15 Nov.		20 May - 5 June	15 May - 15 Nov.

To generate missing data, correlations between wind velocity and equivalent wave height were developed. To recognize all variables, separate correlations should be established for each month and wind direction. However, to increase the strength of any one correlation the number of data sets should be maximized for that correlation; that is, the available data sets should be distributed among few correlations. A compromise was made by combining wind directions into sectors such that the fetch distance and water depth along each wind direction in a sector were approximately constant, and the winds in the sector were all either onshore or offshore. The sectors are shown on Figure 16. Additionally, the months were divided into three seasons - May 15 to July 31, August 1 to September 30, and October 1 to November 15. The use of separate correlations for different wind direction sectors and seasons, implicitly recognizes the effects of such factors as the variable over-water/over-land wind speed ratio, the fetch distance and the water depth, all of which effect the relationship between wind velocity and wave height.

The wave height generated by a given wind also depend on the duration of the wind as illustrated in the following table. Also shown is the time required for the corresponding waves to travel across the fetch distance.

TABLE 3
TIME REQUIRED TO GENERATE MAXIMUM WAVES

Wind Velocity m.p.h.	Fetch Distance miles	Generation Time hours	Wave Period seconds	Wave Velocity m.p.h.	Wave Travel time hours
10	5	2.0	2.0	7	0.7
	20	6.0	3.0	10	2.0
	40	9.0	3.5	12	3.3
20	5	1.3	3.0	10	0.5
	20	3.5	4.2	15	1.3
	40	6.0	5.0	17	2.4
40	5	0.9	4.0	14	0.4
	20	2.5	6.0	21	1.0
	40	4.6	7.0	25	1.6

It will be noted that the lower wind velocities and longer fetches require generation times exceeding 3 hours. For this reason, both the wind speed for the time of the wave recording and the speed for the time three hours earlier were used in the correlation. The direction of the waves was taken to be coincident with the direction of the wind at the time of the wave recording.

Several forms of correlation equations were tried. The following general form of equation gave the best results and was adopted:

$$H_G = C + F_1 \cdot VG_i + F_2 \cdot VG_{i-1} + F_3 \cdot VGB_i + F_4 \cdot VGB_{i-1}$$

where: H_G = equivalent wave height at Gimli in feet

C = constant

F_1 = coefficient

VG_i = Gimli mean wind velocity at time of wave recording - (m.p.h.)

VG_{i-1} = Gimli mean wind velocity 3 hours before wave recording - (m.p.h.)

VGB_i = Grand Beach mean wind at time of wave recording

VGB_{i-1} = Grand Beach mean wind 3 hours before wave recording

Detailed results of the correlation study are included in Annex 2.

Wave periods were correlated with equivalent wave heights to generate wave periods for data sets where wave measurements were missing. Correlations were carried out for the same seasons and sectors used earlier. The form of equation used was the following:

$$T = C + F \cdot H$$

where T = wave period (seconds)

C = a constant

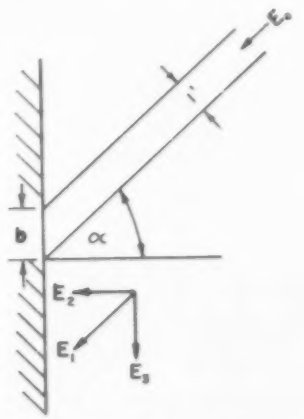
F = a coefficient

H = equivalent wave height (feet)

Detailed results of the correlations are given in Annex 2.

6. APPLICATION OF WAVE AND WIND SETUP CLIMATE TO SPECIFIC REACHES. The climate developed for Gimli and Grand Beach apply directly to limited reaches and require adaptation to others. Certain direction sectors for Gimli and/or Grand Beach which could be expected to apply to specific reaches were selected. For example, a reach of shoreline in the southwest corner of the lake would be considered to be exposed to Gimli climate sectors from north, northeast and east.

The wave energy transmitted toward the shoreline along any reach of shoreline was computed by assuming the shoreline to be straight, ignoring refraction and taking the component of wave energy perpendicular to the shoreline as illustrated below:



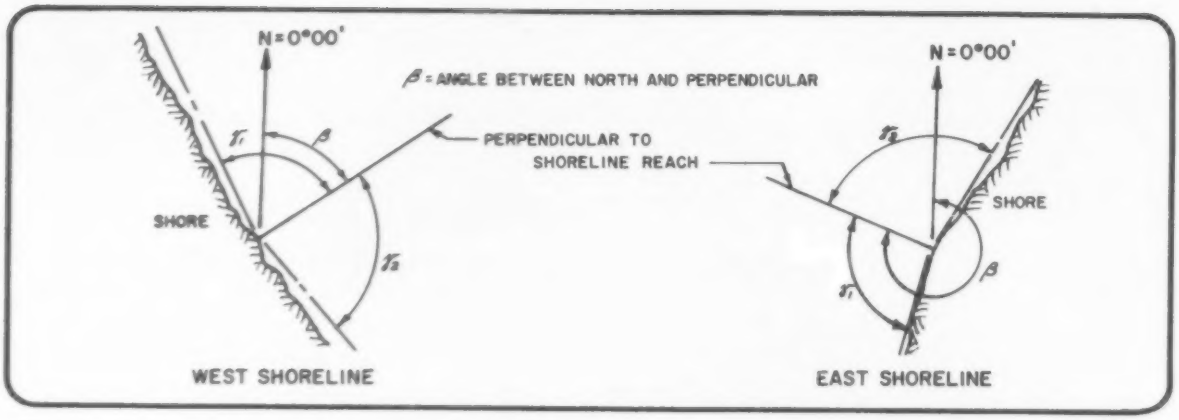
E_0 = deep water wave energy per foot of crest length

E_1 = wave energy per lineal foot of shoreline $= E_0 \times l/b = E_0 \cos\alpha$

E_2 = component of wave energy perpendicular to shore $= E_1 \cos\alpha = E_0 \cos^2\alpha$

E_3 = component of wave energy parallel to shore $E_1 \sin\alpha = E_0 \sin\alpha \cos\alpha$

α = the angle between the wave approach to the shoreline and the perpendicular to the shoreline for a specific reach.



Because of wave refraction, the waves would strike the shoreline more perpendicularly than shown; that is, the ratio E_2/E_1 should be greater than cosα. To simplify and expedite the great number of computations the preceeding approximation was made.

For purposes of calculations the orientation of the shoreline was defined by the azimuth angle (β) of the perpendicular to the shoreline. The wind sectors acting on the shoreline were defined by the angles γ_1 and γ_2 measured counter clockwise and clockwise respectively from the perpendicular to the shoreline as shown in the above sketch.

The "β" angles are measured in a clockwise direction and the "γ" angles are measured with respect to the perpendicular. The following table is a summary of the parameter values used.

TABLE 4

PARAMETERS FOR WAVE ENERGY CALCULATIONS

Reach	β (Degrees)	γ_1 (Degrees)	γ_2 (Degrees)
1	120	90	90
2	60	66	90
3	90	90	90
4	120	90	90
5	90	90	90
6	90	90	90
7	60	60	120
8	115	100	40
9	60	60	75
10	90	90	90
11	90	90	90
12	60	60	75
13	90	90	22.5
14	30	30	60
15	325	90	35
16	260	90	90
17	260	90	90
18	325	90	35
19	260	90	90
20	315	90	45
21	315	45	45
22	260	90	90
23	315	90	45
24	315	90	90

G. DETERMINING EFFECT OF REGULATION ON SHORELINE EROSION.

1. DEVELOPMENT OF SHORE PROFILES. Waves acting on a shoreline will tend to erode the shoreline to a characteristic form in profile. The form of the profile depends on the characteristics of the waves attacking the shoreline, the action of offshore currents, the variation in water levels, the properties of the soils forming the shoreline and the movement of soil parallel to the shoreline. Some of these factors, for example, waves, vary with time. As a result, the profile may also vary with time. However, the profile will retain its form while fluctuating about some mean position or even when shifting horizontally or vertically. This form is called the equilibrium shore profile.

The form of equilibrium profiles has been studied extensively in both the field and laboratory. Bruun (1973)(2) has found that the following equation describes the profile of sandy coasts: $y^{3/2} = px$;

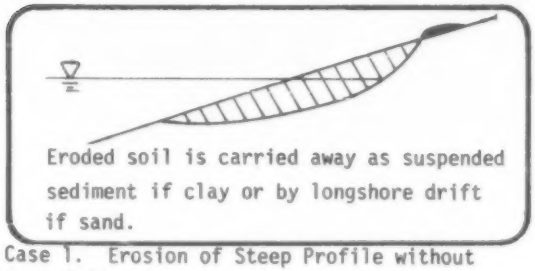
where y = water depth in feet;

x = distance from shoreline in feet;

and p = a constant having a value in the range of 0.08 to 0.10.

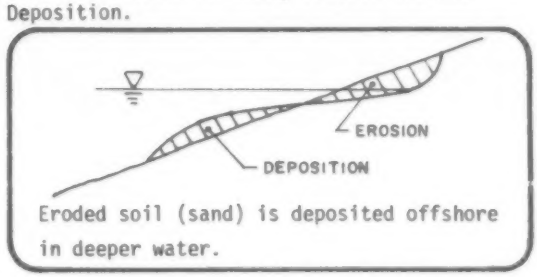
The form of the equation can also be validated by theoretical analysis of friction forces acting at the water-soil interface. The equation illustrates the commonly observed phenomenon that the slope of the profile is steepest at the shoreline and becomes less steep with increasing distance away from the shoreline. Near the shore, in shallow water where wave heights and wave energies are low, sand grains achieve stable equilibrium at relatively steep slopes. As the depth of the water increases, the wave energy increases and a flatter slope is required for equilibrium.

Several classes of profile are described below:



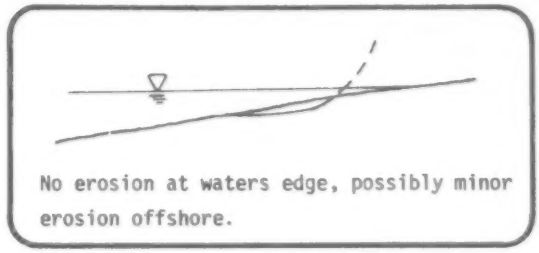
Eroded soil is carried away as suspended sediment if clay or by longshore drift if sand.

Case 1. Erosion of Steep Profile without Deposition.



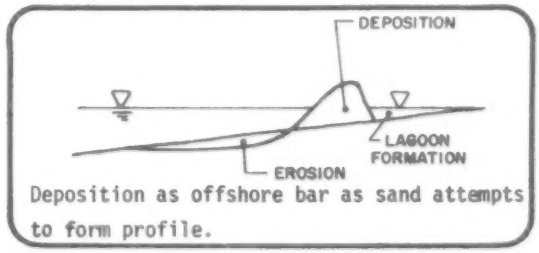
Eroded soil (sand) is deposited offshore in deeper water.

Case 2. Steep Profile, Deposition.



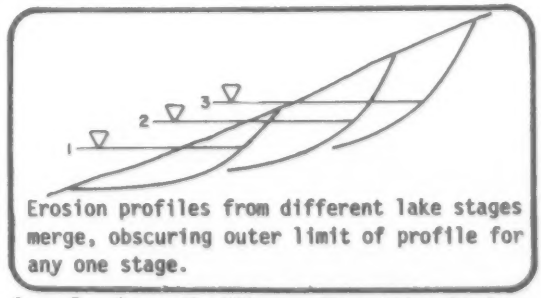
No erosion at waters edge, possibly minor erosion offshore.

Case 3. Flat Profile, No Deposition.



Deposition as offshore bar as sand attempts to form profile.

Case 4. Flat Profile, Deposition.



Erosion profiles from different lake stages merge, obscuring outer limit of profile for any one stage.

Case 5. Steep Profile, no Deposition Rising Water Level (Applies to much of Lake Winnipeg).

The main problem in defining the shore profile lies in establishing the outer limit of the profile formed by the erosion process. Unless the offshore profile is quite steep so that the erosion profile appears as a bench cut into a steeper slope, it is generally not possible to define the outer limit of the erosion profile with precision. The main factors likely influencing the depth to which erosion (or movement of sand) occurs are the height of waves and the type of soil (or size of particles). Several published data are tabulated below.

TABLE 5

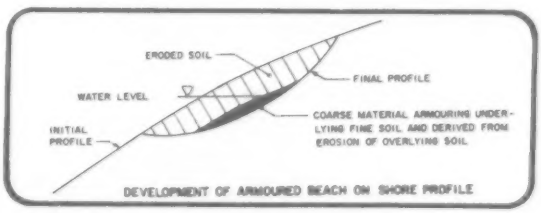
DEPTH TO WHICH EROSION OCCURS

Site	Wave Height Feet	Water Depth Feet	Soil Type
California	10	30	sand
Denmark	up to 12'	60 - 70	sand .2-.3 mm
California	4	30	sand .15-.10
New Jersey	4	30	sand .34 mm
Japan	6	20	sand .13 mm
Baltic	H	3H	sand
England	3	18 - 24	pebbles
Ocean	4	20	sand .25 mm

Examination of the data suggests that the depth to which erosion takes place is of the order of 5 times the wave height. The variation in the values noted above is to be expected since the rate of sand movement decreases very gradually with depth. Additionally, the wave heights are highly variable so that any reported value is likely to be a somewhat arbitrary choice.

If one selects a typical wave height of 3 feet for Lake Winnipeg one would expect erosion to occur to a depth of approximately 15 feet. Examination of the shore profiles for lines 032 and 031 which have eroded 800 feet or more within the last 100 years indicates that areas that were above water 100 years ago have now been eroded to elevation 707, or about 6 feet below the long term mean lake level during this period. If one extrapolates the shoreline recession rate of the last 100 years into the past, one finds that areas which were above water 200 years ago have now been eroded to elevation 705, or 8 feet below the mean lake level. The lake bottom is very level possibly indicating near equilibrium conditions. Other sections with lesser rates of shoreline recession suggest that erosion extends to about elevation 700, or about 4 times the wave height. The lines referred to above were in clay or clayey till soil. Examination of profiles in sands suggest the sand is moved to a similar depth under the action of waves.

The preceeding discussion applied to profiles in homogeneous soil. Where the profile falls within two or more soils having different resistance to erosion, the shape of the profile will be modified accordingly. For example, if the profile consists of an upper erodible soil and a lower erosion resistant soil, the shoreline may recede rapidly in a horizontal direction in the upper soil, but the profile may not penetrate the lower soil. Similarly, if the eroding soil contains sufficient coarse gravel or boulders, removal of fine grained soil may leave an armour layer of coarse particles which protects the underlying soil against further erosion and thereby arrests the erosion process. Depending on the quantity of coarse particles produced by the erosion process, the erosion may be arrested at an elevation below, at, or above the mean water level. In this case, the shore profile may be characterized by the elevation at which erosion is arrested.
The development of a shore profile in a soil containing significant quantities of coarse material may be illustrated as follows:

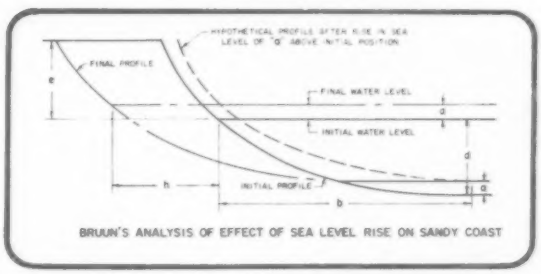

ERODED SOIL
FINAL PROFILE
WATER LEVEL
COARSE MATERIAL ARMOURING UNDERLYING FINE SOIL AND DERIVED FROM EROSION OF OVERLYING SOIL
INITIAL PROFILE
DEVELOPMENT OF ARMOURED BEACH ON SHORE PROFILE

Erosion will be arrested when sufficient coarse material has been generated to protect the underlying soil. Waves will sort the coarse material on the beach with the coarsest particles remaining in areas having the highest wave forces and smaller particles in areas of lower wave forces. At infrequent intervals, high waves associated with high wind setup and high water levels may extend above the armour layer and attack the unprotected soil. In these cases, sudden and large shoreline recessions may be observed.

A typical profile was defined for each reach of shoreline. The outer limit of the profile was defined by the elevation 705 contour unless evidence indicated some other limit to be more accurate. It was assumed that each profile was associated with the recorded lake levels for the period 1928-1966. The reaches are shown on Figures 12-1 to 12-5, 16 and the typical profiles are shown on Figure 17.

2. CHANGES IN SHORE PROFILE RESULTING FROM CHANGES IN LAKE LEVELS. Where the shore profile has been formed in a homogeneous soil by wave action at a certain water level, a change in water level will cause a corresponding shift horizontally and vertically in the shore profile.

Bruun (1973) (2) has reported on the effect of a rise in sea level opposite a sandy coast as follows:



BRUUN'S ANALYSIS OF EFFECT OF SEA LEVEL RISE ON SANDY COAST

a = rise in sea level
b = profile length of shelf width over which movement of sand takes place
d = depth to which movement of sand takes place
e = height of bank above water level
h = shoreline recession caused by rise in sea level.

A rise in sea level of "a" feet demands a corresponding profile rise of the profile from the initial profile to the hypothetical profile. The required fill volume is a·b. The fill volume is generated by a horizontal landward shift of "h" feet from the hypothetical to the final position. The volume of fill generated is (d + e)h. When volumes are equated; a·b = (d + e)h, the following expression is obtained: h = a·b/(d + e). This process can be illustrated by using typical values for Grand Beach.

a = assume 0.33 feet
b = 600
d = 10
e = 15
h = a·b/(d + e) = .33(600)/(10 + 5) = 8 feet

The result indicates that a rise in lake level of 0.33 feet would cause a shoreline recession of 8 feet. Bruun's analysis applies equally well to a fall in sea level in which case the shore profile advances. The analysis assumes that material eroded from one portion of the profile is deposited over another portion of the profile. The new profile is formed partly by erosion and partly by deposition.

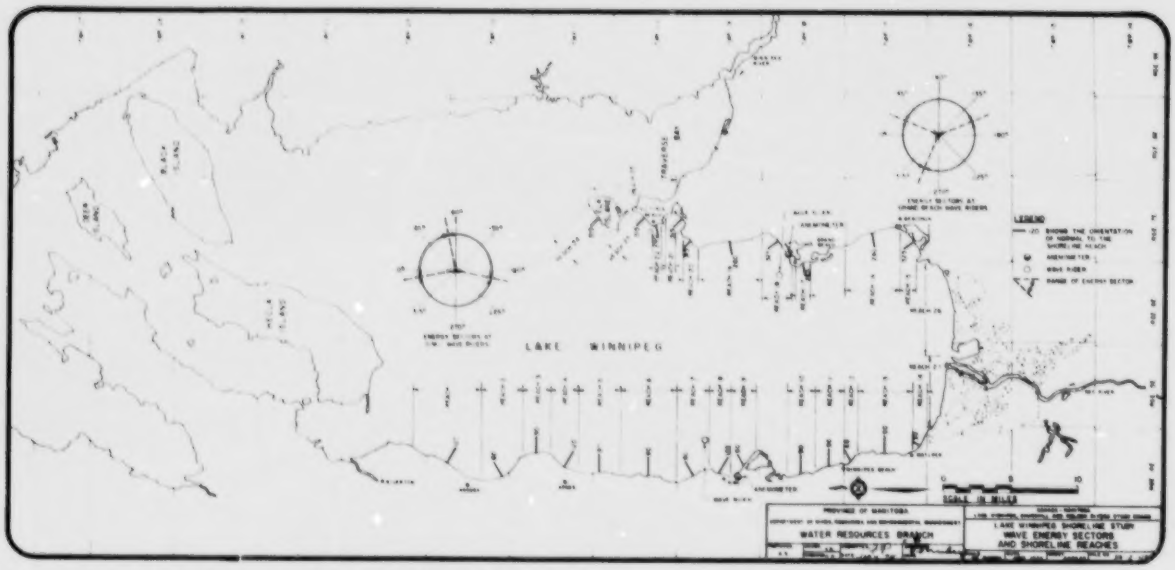


Figure 16. Wave Energy Sectors and Shoreline Reaches.

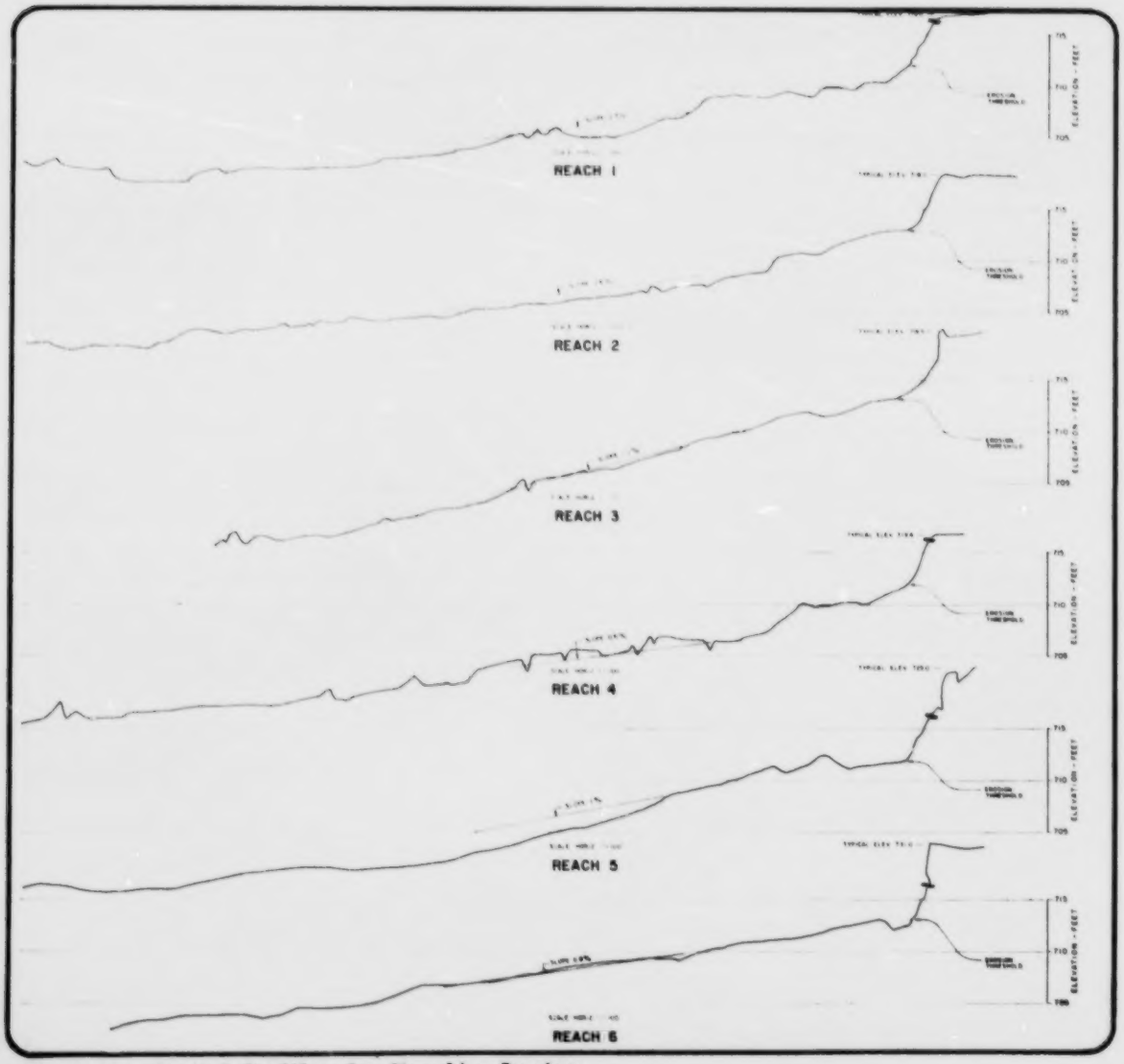


Figure 17. Typical Profiles for Shoreline Reaches.

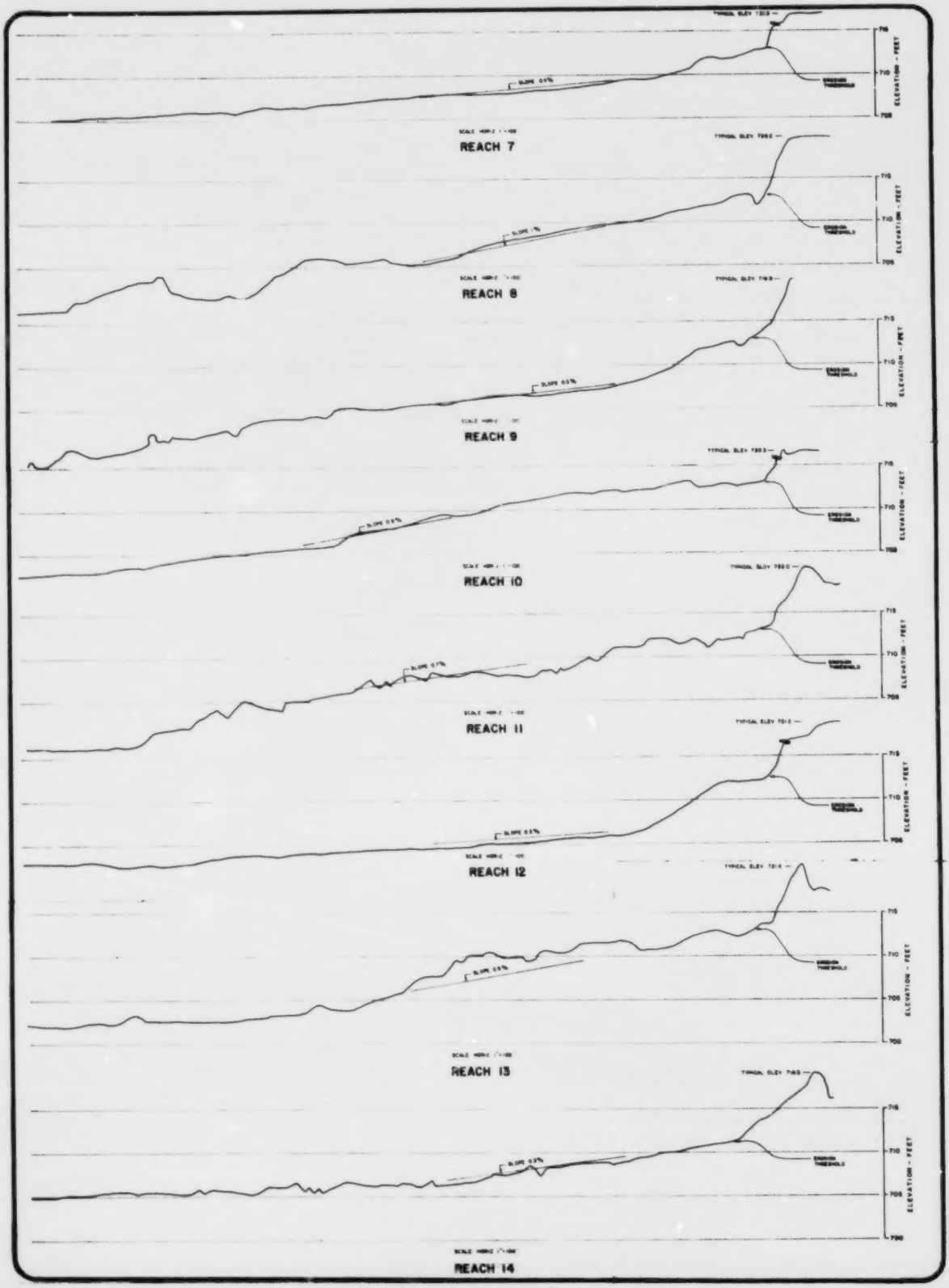


Figure 17 Typical Profiles For Shoreline Reached Continued.

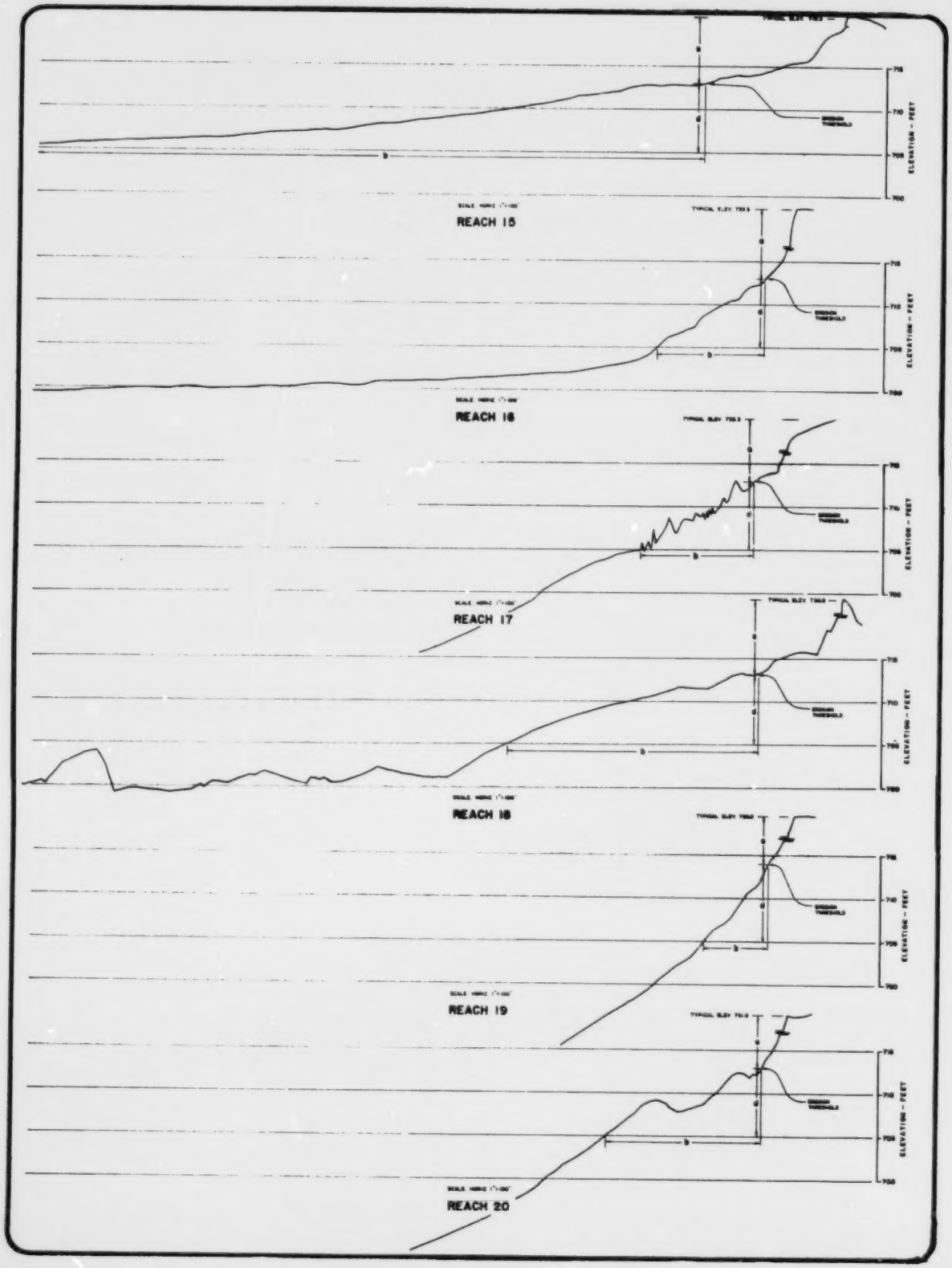


Figure 17 Typical Profiles For Shoreline Reached Continued.

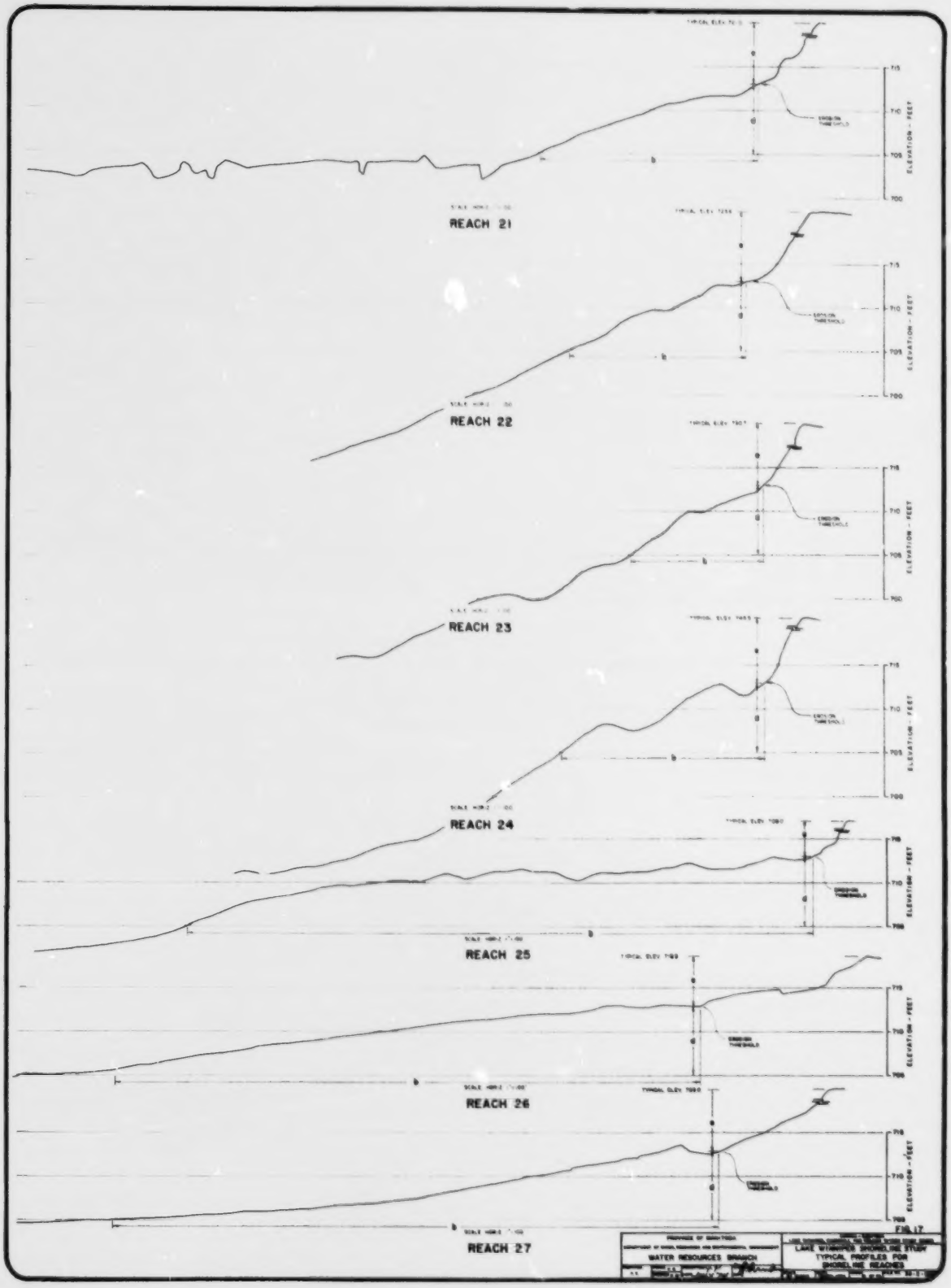
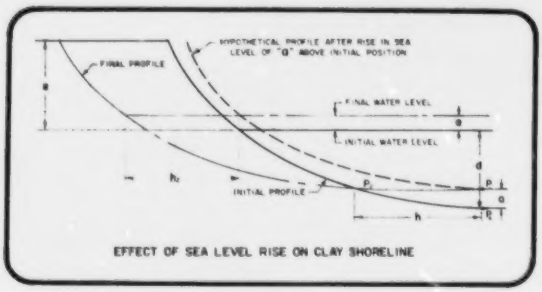


Figure 17 Typical Profiles For Shoreline Reached Continued.

Where the profile falls within fine grained soil which is carried away as it is eroded from one part of the profile, the new profile would be formed entirely by erosion. In this case Bruun's analysis should be modified as follows:



EFFECT OF SEA LEVEL RISE ON CLAY SHORELINE

a = rise in sea level
d = depth to which erosion takes place
h_1 = profile length or shelf width over which depth "d" decreases by amount "a"
m = slope of profile at depth "d" = a/h_1
h_2 = shoreline recession caused by rise in sea level ($h_2 = h_1$)

A rise in sea level of "a" feet requires a corresponding rise of the profile from the initial profile to the hypothetical profile. This rise is accomplished by a landward shift of "h" feet from the hypothetical profile to the final profile; that is, the point "P" shifts from P_0 to P_1 to P_2. By geometry $a/h = m/1$ and $h = a/m$. In the case of clay profiles both the point "P" and the slope of the profile at the point "P" are often ill defined and must be selected somewhat arbitrarily. For this reason, the slope at "P_0" was approximated by the overall slope over the vertical distance from elevation 705 to elevation 710. This procedure used a criterion which could be applied on a consistent basis to all clay profiles yielding shoreline changes which could be expected to occur within a reasonable period of time. The changes may be illustrated by applying typical values for the west shore:

If a = assume 0.3 feet;
and m = 0.6%
then h = a/m = 50 feet

A rise in lake level of 0.3 feet would cause a shoreline recession of 50 feet. A fall in lake level opposite a clay bank will not cause the shore profile to advance. Such profiles are generally eroding continuously. As a result, a fall in lake level will be reflected in a temporary reduced rate of erosion. The reduction in rate of erosion when integrated over the time over which it applies would equal the computed hypothetical advance.

Where the profile falls within a soil containing sufficient coarse particles to produce an armour layer, sufficient to completely arrest further vertical erosion, the form of the profile depends mainly on the proportion and size of coarse particles in the eroding soil and on the height of the eroding bank. Changes in profile will only result when infrequent high waves associated with high wind setup and high lake levels attack the unprotected soil above the armoured beach. Wave energies applied to the shoreline at lower elevations will have no effect. At partially armoured beaches, some intermediate condition will apply.

Numerous profiles exist where a thin layer of sand covers underlying clay. The sand has an armouring effect in the case of moderate waves and shore currents, but is inadequate to protect the clay against erosion by storm waves. The sand appears to shift landward with the profile as the shoreline recedes. It is effective in reducing the rate of shoreline recession, but not in arresting it. Most of these profiles were considered to behave as clay profiles and were treated accordingly.

In the case where structures are located at the shoreline the effect of regulation will depend on the depth of water adjacent to the structure. Where a structure is located in a depth of water greater than the wave breaking depth, the slightly increased water levels under regulation will have no effect. Where a structure is located in a depth of water less than the wave breaking depth, as in the case of most shoreline erosion protection walls, higher water levels under regulation will increase the amount of wave energy impinging on the structure. In this case the profile shift would occur only downward adjacent to the structure, since the horizontal shift is controlled.

3. CONCEPT OF EFFECTIVE LAKE LEVEL. Where the change in the mean lake level is small relative to the variation in levels about the mean, the effect of a change in the mean level may be less than the effect of changes in the variation about the mean, or in the seasonal distribution of levels. Hence, it is necessary to introduce the concept of an effective lake level, such that the change in effective lake level will be a measure of the change in levels introduced by regulation. The effective lake level is defined to be a constant lake level for each condition (recorded, unregulated, or regulated). The rate of erosion would be equal to the long term average rate of erosion under variable water levels occurring under recorded, unregulated and regulated conditions.

It has been noted earlier that a change in effective lake level will cause a corresponding one time vertical and horizontal adjustment of the shore profile. These adjustments depend on the change in effective lake level, rather than on the absolute values of the levels. The absolute values of effective lake level may be defined and computed in a somewhat arbitrary fashion so long as the change in computed levels is a realistic measure of the change attributable to regulation.

4. VARIATION IN RATE OF EROSION WITH LAKE LEVELS. The variation in rate of erosion with lake level for any given wave and wind setup climate was approximated from the variation in the "wave energy effective in causing erosion" with lake level for the given wave and wind setup climate. The computation of the "wave energy effective in causing erosion" is outlined in the following sections:

Wind generated waves are the main cause of erosion. The wave energy transmitted forward toward the shore is essentially constant up to the point where the wave breaks, and is equal to one half of the total deep water wave energy. Where the wind (and wave) direction is not perpendicular to the shore a wave refraction correction should be applied.

When a wave approaches the shore, it breaks when the water depth decreases to approximately 1.3 times the wave height. After the wave breaks, it reforms into smaller waves which continue to the shore and run up the shore slope. The elevation of the point of maximum run up above the still water level is given by the formula: $R_u = 2.3H^{1/2}T \tan\alpha$

where R_u = run up above still water level (feet)

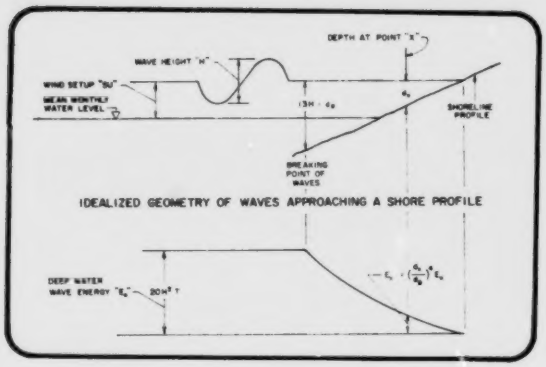
H = wave height (feet)

T = wave period (seconds)

$\tan\alpha$ = inclination of shore slope from horizontal

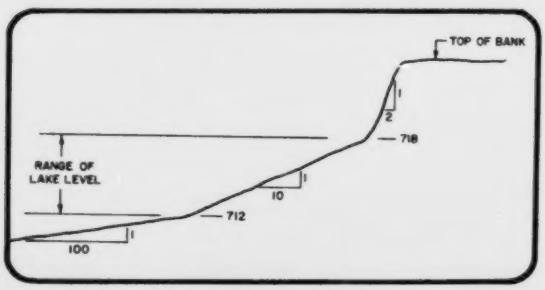
For very flat slopes the run up is small and may be neglected. For example, if H = 3, T = 4, $\tan\alpha = 0.01$, then $R_u = 0.16$. In this report run up has been neglected.

The wave energy decreases from the deep water wave energy at the point of breaking to zero at the point of maximum run up. At any intermediate point the wave energy may be approximated by considering it to be proportional to the fourth power of the depth of water at that point as shown in the following Figure.


DEPTH AT POINT "x"
WAVE HEIGHT "H"
WIND SETUP "SU"
MEAN MONTHLY WATER LEVEL
SHORELINE PROFILE
BREAKING POINT OF WAVES
IDEALIZED GEOMETRY OF WAVES APPROACHING A SHORE PROFILE
DEEP WATER WAVE ENERGY

This method of analysis is based on an analogous method used by the Canada Department of Public Works, Marine Engineering Division, Coastal Engineering Section in a study of the effect of regulating the Great Lakes. (Kolberg 1973) (3).

Examination of the shore profiles from Lake Winnipeg (excluding those armoured by gravel and boulders) indicates that a large number are characterized by a very flat offshore slope (1% to 2% slope) a steeper beach slope (typically 10%) between the minimum and maximum water level followed by an angle of repose slope (typically 50%) above the maximum water level. In some cases of low lying shore lands, the beach slope extends up to the natural ground level. A typical profile is illustrated below:



Study of recorded erosion and shore profiles indicates that erosion occurs down to at least elevation 705; that is, also on the flat offshore slope. Erosion also occurs on the beach slope as demonstrated by recorded erosion of profiles where the beach slope extends to the upland. Erosion is clearly not limited to the angle of repose slope above the beach slope. However, for the purpose of computing the effect of the lake level on shoreline erosion, it was assumed that the shoreline recession was proportional to the wave energy dissipated on or above the beach slope. This assumption is somewhat arbitrary, but is necessary to introduce the widely observed effect that for any given profile and wave climate, erosion is more rapid at high lake levels than at low levels. The energy dissipated on or above the beach slope hereafter is called the "wave energy effective in causing erosion", and the elevation on the shore profile above or beyond which the wave energy is considered to be effective in causing erosion is called the "erosion threshold elevation". The wave energy transmitted past the "erosion threshold" which is considered to be effective in causing shoreline erosion is computed from the equation $E_x = [{}^{d_x}/_{d_B}]^4 E_0$.

Some confirmation of the validity of this approach can be obtained by comparing wave energies and erosion rates measured during the course of this study and reported in Annex 4.

The wind set up and wave climate developed earlier was then applied to various typical shore profiles defined for each reach to compute the wave energy effective in causing erosion. A separate computation was made for each reach, each month, and for a range of mean monthly lake levels from 8 feet above

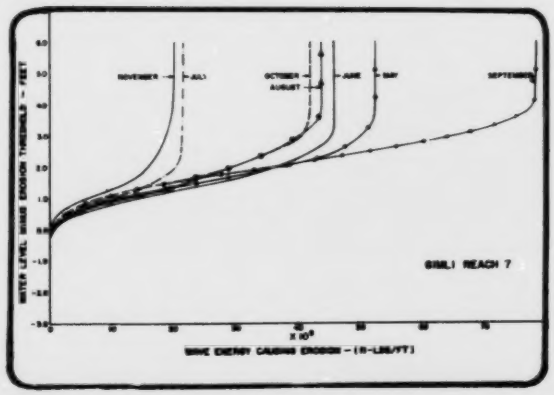


Figure 18 Wave Energy Curves.

to 4 feet below the erosion threshold elevation. The results of the computation were presented in the form of a graph of wave energy causing erosion versus mean monthly lake level minus erosion threshold elevation for a specific reach and month. Figure 18 is an example of such a graph which is hereafter referred to as a wave energy curve.

5. COMPUTATION OF EFFECTIVE LAKE LEVEL UNDER RECORDED, UNREGULATED AND REGULATED CONDITIONS. The effective lake level for each reach and condition was calculated as follows:

The wave energy per month effective in causing erosion was computed for each month by integrating the lake level duration curve with the wave energy curve. The wave energy curve was entered with the computed wave energy per month to determine the constant lake level having the same wave energy per month. This level was earlier defined to be the "effective lake level". An example of the computations for reach 7 is included in Table 6.

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =MAY

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.15	713.00	3.15	50.77	2.03
90- 96	0.06	715.80	713.00	2.80	38.30	2.30
80- 90	0.10	714.65	713.00	1.65	23.26	2.33
60- 80	0.20	713.85	713.00	0.85	8.54	1.71
40- 60	0.20	713.08	713.00	0.08	0.65	0.13
20- 40	0.20	712.55	713.00	-0.45	0.02	0.00
10- 20	0.10	711.45	713.00	-1.55	0.0	0.0
0- 10	0.10	710.60	713.00	-2.40	0.0	0.0

SUMMATION OF WAVE ENERGY = 8.50
EFFECTIVE MEAN MONTHLY WATER LEVEL = 713.83

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.35	713.00	3.35	51.57	2.06
90- 96	0.06	716.20	713.00	3.20	50.97	3.06
80- 90	0.10	714.70	713.00	1.70	29.63	2.96
60- 80	0.20	714.15	713.00	1.15	15.39	3.08
40- 60	0.20	713.58	713.00	0.58	4.24	0.85
20- 40	0.20	713.02	713.00	0.02	0.33	0.07
10- 20	0.10	712.13	713.00	-0.87	0.0	0.0
0- 10	0.10	711.41	713.00	-1.59	0.0	0.0

SUMMATION OF WAVE ENERGY = 12.08
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.02

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.58	713.00	2.58	46.21	1.85
90- 96	0.06	715.00	713.00	2.00	37.22	2.23
80- 90	0.10	714.82	713.00	1.82	32.66	3.27
60- 80	0.20	714.58	713.00	1.58	24.57	4.91
40- 60	0.20	714.00	713.00	1.00	11.46	2.29
20- 40	0.20	713.35	713.00	0.35	2.08	0.42
10- 20	0.10	712.75	713.00	-0.25	0.11	0.01
0- 10	0.10	712.30	713.00	-0.70	0.0	0.0

SUMMATION OF WAVE ENERGY = 14.98
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.13

Table 6

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =JUNE

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	717.00	713.00	4.00	45.47	1.83
90- 96	0.06	715.75	713.00	2.75	43.91	2.63
80- 90	0.10	715.03	713.00	2.03	36.73	3.67
60- 80	0.20	714.83	713.00	1.83	32.93	6.59
40- 60	0.20	713.63	713.00	0.63	6.52	1.30
20- 40	0.20	712.68	713.00	-0.32	0.19	0.04
10- 20	0.10	711.90	713.00	-1.10	0.0	0.0
0- 10	0.10	710.83	713.00	-2.17	0.0	0.0

SUMMATION OF WAVE ENERGY = 16.07
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.09

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	717.00	713.00	4.00	45.47	1.83
90- 96	0.06	715.55	713.00	2.55	42.69	2.56
80- 90	0.10	714.78	713.00	1.78	31.42	3.19
60- 80	0.20	714.65	713.00	1.65	29.30	5.86
40- 60	0.20	713.82	713.00	0.82	10.32	2.06
20- 40	0.20	712.85	713.00	-0.15	0.34	0.07
10- 20	0.10	712.16	713.00	-0.84	0.01	0.00
0- 10	0.10	711.16	713.00	-1.84	0.0	0.0

SUMMATION OF WAVE ENERGY = 15.58
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.07

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.05	713.00	2.05	44.53	1.78
90- 96	0.06	715.15	713.00	2.15	38.17	2.29
80- 90	0.10	715.00	713.00	2.00	36.37	3.64
60- 80	0.20	714.45	713.00	1.45	25.03	5.01
40- 60	0.20	714.28	713.00	1.28	20.83	4.17
20- 40	0.20	713.05	713.00	0.05	0.81	0.16
10- 20	0.10	712.85	713.00	-0.15	0.34	0.03
0- 10	0.10	712.40	713.00	-0.60	0.02	0.00

SUMMATION OF WAVE ENERGY = 17.88
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.13

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =JULY

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	717.30	713.00	4.30	21.53	0.86
90- 96	0.06	716.22	713.00	3.22	21.37	1.28
80- 90	0.10	715.70	713.00	2.70	21.21	2.12
60- 80	0.20	714.68	713.00	1.68	17.46	3.57
40- 60	0.20	714.03	713.00	1.03	10.10	2.02
20- 40	0.20	713.02	713.00	0.02	0.33	0.07
10- 20	0.10	712.23	713.00	-0.80	0.00	0.00
0- 10	0.10	710.75	713.00	-2.25	0.0	0.0

SUMMATION OF WAVE ENERGY = 9.92
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.02

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	717.15	713.00	4.15	21.49	0.86
90- 96	0.06	716.00	713.00	3.00	21.34	1.28
80- 90	0.10	715.60	713.00	2.60	21.16	2.12
60- 80	0.20	714.80	713.00	1.80	18.73	3.75
40- 60	0.20	714.03	713.00	1.03	10.10	2.02
20- 40	0.20	712.85	713.00	-0.15	0.17	0.03
10- 20	0.10	712.41	713.00	-0.59	0.01	0.00
0- 10	0.10	711.00	713.00	-2.00	0.0	0.0

SUMMATION OF WAVE ENERGY = 10.06
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.03

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.80	713.00	2.80	21.25	0.85
90- 96	0.06	715.14	713.00	2.14	20.46	1.23
80- 90	0.10	715.00	713.00	2.00	20.20	2.02
60- 80	0.20	715.00	713.00	2.00	20.20	4.04
40- 60	0.20	714.60	713.00	1.60	17.46	3.57
20- 40	0.20	713.78	713.00	0.78	6.57	1.31
10- 20	0.10	713.00	713.00	0.0	0.24	0.02
0- 10	0.10	712.45	713.00	-0.55	0.01	0.00

SUMMATION OF WAVE ENERGY = 13.05
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.24

Table 6 Continued.

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =AUG

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	717.00	713.00	4.00	43.03	1.75
90- 96	0.06	716.32	713.00	3.32	41.87	2.51
80- 90	0.10	715.70	713.00	2.70	37.51	3.75
60- 80	0.20	714.60	713.00	1.60	23.77	4.75
40- 60	0.20	714.46	713.00	1.46	21.53	4.31
20- 40	0.20	712.93	713.00	-0.07	0.42	0.08
10- 20	0.10	712.00	713.00	-1.00	0.0	0.0
0- 10	0.10	710.65	713.00	-2.35	0.0	0.0

SUMMATION OF WAVE ENERGY = 17.16
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.23

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.70	713.00	3.70	43.39	1.74
90- 96	0.06	715.75	713.00	2.75	37.87	2.27
80- 90	0.10	715.40	713.00	2.40	34.79	3.48
60- 80	0.20	714.40	713.00	1.40	23.77	4.75
40- 60	0.20	714.06	713.00	1.06	13.81	2.76
20- 40	0.20	712.82	713.00	-0.18	0.32	0.06
10- 20	0.10	711.88	713.00	-1.12	0.0	0.0
0- 10	0.10	711.25	713.00	-1.75	0.0	0.0

SUMMATION OF WAVE ENERGY = 15.07
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.12

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.43	713.00	2.43	35.17	1.41
90- 96	0.06	715.03	713.00	2.03	30.04	1.80
80- 90	0.10	715.00	713.00	2.00	29.66	2.97
60- 80	0.20	715.00	713.00	2.00	29.66	5.93
40- 60	0.20	714.97	713.00	1.97	29.22	5.84
20- 40	0.20	713.93	713.00	0.93	11.46	2.29
10- 20	0.10	713.03	713.00	0.03	0.70	0.07
0- 10	0.10	712.35	713.00	-0.65	0.02	0.00

SUMMATION OF WAVE ENERGY = 20.32
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.40

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =SEPT

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.52	713.00	3.52	74.71	2.99
90- 96	0.06	716.06	713.00	3.06	66.70	4.00
80- 90	0.10	715.33	713.00	2.33	47.30	4.73
60- 80	0.20	714.45	713.00	1.45	18.74	3.75
40- 60	0.20	713.60	713.00	0.60	3.31	0.66
20- 40	0.20	712.68	713.00	-0.32	0.13	0.03
10- 20	0.10	711.59	713.00	-1.41	0.0	0.0
0- 10	0.10	710.35	713.00	-2.65	0.0	0.0

SUMMATION OF WAVE ENERGY = 16.16
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.34

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.41	713.00	3.41	72.98	2.92
90- 96	0.06	715.75	713.00	2.75	59.30	3.56
80- 90	0.10	714.98	713.00	1.98	35.62	3.56
60- 80	0.20	714.28	713.00	1.28	14.74	2.95
40- 60	0.20	713.28	713.00	0.28	1.30	0.26
20- 40	0.20	712.47	713.00	-0.53	0.04	0.01
10- 20	0.10	711.40	713.00	-1.60	0.0	0.0
0- 10	0.10	710.70	713.00	-2.30	0.0	0.0

SUMMATION OF WAVE ENERGY = 13.26
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.22

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.07	713.00	2.07	38.61	1.54
90- 96	0.06	715.00	713.00	2.00	36.28	2.18
80- 90	0.10	715.00	713.00	2.00	36.28	3.63
60- 80	0.20	715.00	713.00	2.00	36.28	7.26
40- 60	0.20	714.95	713.00	1.95	34.64	6.93
20- 40	0.20	713.84	713.00	0.85	0.34	0.07
10- 20	0.10	712.80	713.00	-0.20	0.10	0.02
0- 10	0.10	712.18	713.00	-0.82	0.01	0.00

SUMMATION OF WAVE ENERGY = 22.02
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.59

Table 6 Continued.

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =OCT

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.50	713.00	3.50	41.67	1.67
90- 96	0.06	715.85	713.00	2.85	39.57	2.37
80- 90	0.10	714.70	713.00	1.70	23.16	2.32
60- 80	0.20	713.93	713.00	0.93	0.15	1.63
40- 60	0.20	713.10	713.00	0.10	1.23	0.25
20- 40	0.20	712.25	713.00	-0.75	0.00	0.00
10- 20	0.10	711.13	713.00	-1.87	0.0	0.0
0- 10	0.10	710.25	713.00	-2.75	0.0	0.0

SUMMATION OF WAVE ENERGY = 8.24
EFFECTIVE MEAN MONTHLY WATER LEVEL = 713.94

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.62	713.00	2.62	37.79	1.51
90- 96	0.06	715.25	713.00	2.25	33.23	1.99
80- 90	0.10	714.58	713.00	1.58	20.58	2.06
60- 80	0.20	713.82	713.00	0.82	6.78	1.36
40- 60	0.20	713.10	713.00	0.10	0.84	0.17
20- 40	0.20	712.25	713.00	-0.75	0.00	0.00
10- 20	0.10	711.10	713.00	-1.90	0.0	0.0
0- 10	0.10	710.65	713.00	-2.35	0.0	0.0

SUMMATION OF WAVE ENERGY = 7.09
EFFECTIVE MEAN MONTHLY WATER LEVEL = 713.84

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.00	713.00	2.00	29.61	1.18
90- 96	0.06	715.00	713.00	2.00	29.61	1.78
80- 90	0.10	715.00	713.00	2.00	29.61	2.96
60- 80	0.20	715.00	713.00	2.00	29.61	5.92
40- 60	0.20	714.82	713.00	1.82	25.74	5.15
20- 40	0.20	713.65	713.00	0.65	4.65	0.93
10- 20	0.10	712.12	713.00	-0.88	0.00	0.00
0- 10	0.10	712.05	713.00	-0.95	0.00	0.00

SUMMATION OF WAVE ENERGY = 17.92
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.45

INTEGRATION OF EROSION ENERGY VECTORS
AND MONTHLY WATER LEVEL DURATIONS
(ENERGY IN MILLION FT.LB./FT)

REACH =REACH NUMBER 7
MONTH =NOV

RECORDED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	716.43	713.00	3.43	19.69	0.79
90- 96	0.06	715.35	713.00	2.35	16.84	1.01
80- 90	0.10	714.42	713.00	1.42	11.95	1.20
60- 80	0.20	713.64	713.00	0.64	2.78	0.56
40- 60	0.20	712.91	713.00	-0.09	0.07	0.01
20- 40	0.20	712.02	713.00	-0.98	0.0	0.0
10- 20	0.10	710.90	713.00	-2.10	0.0	0.0
0- 10	0.10	710.40	713.00	-2.60	0.0	0.0

SUMMATION OF WAVE ENERGY = 3.55
EFFECTIVE MEAN MONTHLY WATER LEVEL = 713.72

MODIFIED HISTORIC CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.45	713.00	2.45	17.15	0.69
90- 96	0.06	714.93	713.00	1.93	15.35	0.92
80- 90	0.10	714.30	713.00	1.30	10.35	1.03
60- 80	0.20	713.68	713.00	0.68	3.11	0.62
40- 60	0.20	712.91	713.00	-0.09	0.07	0.01
20- 40	0.20	712.15	713.00	-0.85	0.0	0.0
10- 20	0.10	711.02	713.00	-1.98	0.0	0.0
0- 10	0.10	710.50	713.00	-2.50	0.0	0.0

SUMMATION OF WAVE ENERGY = 3.28
EFFECTIVE MEAN MONTHLY WATER LEVEL = 713.70

REGULATED CONDITIONS

% OF TIME LESS THAN	DURATION	MONTHLY LEVEL	EROSION THRESHOLD	DIFF.	ENERGY PER MO	DURATION X ENERGY
96-100	0.04	715.80	713.00	2.80	15.73	0.63
90- 96	0.06	715.80	713.00	2.80	15.73	0.94
80- 90	0.10	715.80	713.00	2.80	15.73	1.57
60- 80	0.20	715.80	713.00	1.80	15.08	3.02
40- 60	0.20	714.63	713.00	1.63	13.72	2.74
20- 40	0.20	713.65	713.00	0.65	2.88	0.56
10- 20	0.10	712.64	713.00	-0.36	0.03	0.00
0- 10	0.10	712.00	713.00	-1.00	0.0	0.0

SUMMATION OF WAVE ENERGY = 9.47
EFFECTIVE MEAN MONTHLY WATER LEVEL = 714.23

Table 6 Continued.

TABLE 7

CALCULATION OF OPEN-WATER EFFECTIVE LAKE LEVEL

REACH 7 EROSION THRESHOLD 713.0 CONDITION Recorded

Month	Wave Energy Per Month	Percent Energy	Effective Mon. Level	Weighted Eff. Level
1/2 May	8.30	10.7	713.93	0.41
June	16.07	20.2	714.09	0.83
July	9.92	12.4	714.02	0.50
Aug.	17.16	21.6	714.25	0.91
Sept.	16.16	20.3	714.34	0.89
Oct.	8.24	10.5	713.94	0.41
1/2 Nov.	3.55	4.5	713.72	0.17
	79.60		OPEN-WATER EFFECTIVE LAKE LEVEL =	714.11

REACH 7 EROSION THRESHOLD 713.0 CONDITION Unregulated

Month	Wave Energy Per Month	Percent Energy	Effective Mon. Level	Weighted Eff. Level
1/2 May	12.08	15.8	714.02	0.61
June	15.58	20.4	714.07	0.83
July	10.06	15.2	714.03	0.55
Aug.	15.07	19.6	714.12	0.91
Sept.	13.26	17.4	714.22	0.78
Oct.	7.09	9.3	713.94	0.36
1/2 Nov.	3.28	4.3	713.70	0.16
	76.42		OPEN-WATER EFFECTIVE LAKE LEVEL =	714.07

REACH 7 EROSION THRESHOLD 713.0 CONDITION Regulated

Month	Wave Energy Per Month	Percent Energy	Effective Mon. Level	Weighted Eff. Level
1/2 May	11.98	1.30	714.15	0.51
June	17.08	14.8	714.13	0.61
July	15.05	11.5	714.24	0.48
Aug.	20.32	17.6	714.10	0.78
Sept.	22.82	19.6	714.50	0.90
Oct.	17.42	15.5	714.35	0.69
1/2 Nov.	9.47	8.2	714.23	0.35
	113.64		OPEN-WATER EFFECTIVE LAKE LEVEL =	714.55

A weighted effective lake level was computed by weighting the effective lake level for each month according to the percentage of the annual wave energy applied during the month. An example of the computations for reach 7 is included in Table 7. The total annual erosion wave energy and the effective lake levels computed on this basis are summarized in Table 8.

6. EFFECTS OF CHANGES IN EFFECTIVE LAKE LEVELS. The shore profile adjustments resulting from changes in effective lake levels were estimated according to the principles outlined earlier. It was assumed that the present (1972) shore profiles correspond to recorded conditions. The parameters utilized in the computations and the computed profile changes are summarized in Table 9. The symbols used

TABLE 8
EROSION ENERGY AND EFFECTIVE LAKE LEVELS

Reach	Erosion Threshold Elevation	Total Erosion Wave Energy Recorded (ft.lbs/ft)	Unregulated (ft.lbs/ft)	Regulated (ft.lbs/ft)	Effective Lake Levels Recorded	Unregulated	Regulated
1	712.0	117.38×10^6	113.15×10^6	167.23×10^6	713.69	713.65	714.11
2	713.0	79.36×10^6	76.23×10^6	115.36×10^6	714.09	714.05	714.34
3	713.0	72.11×10^6	67.37×10^6	101.93×10^6	714.16	714.11	714.37
4	712.0	117.38×10^6	113.19×10^6	167.23×10^6	713.69	713.69	714.11
5	712.0	127.15×10^6	125.27×10^6	180.56×10^6	713.58	713.56	714.01
6	713.0	72.11×10^6	67.37×10^6	101.93×10^6	714.16	714.11	714.37
7	713.0	79.60×10^6	76.42×10^6	115.64×10^6	714.11	714.07	714.35
8	713.0	54.92×10^6	50.47×10^6	76.02×10^6	714.21	714.13	714.40
9	713.0	78.00×10^6	74.99×10^6	113.49×10^6	714.09	714.03	714.32
10	713.0	72.11×10^6	67.37×10^6	101.93×10^6	714.16	714.11	714.37
11	713.0	72.11×10^6	67.37×10^6	101.93×10^6	714.16	714.11	714.37
12	713.0	78.00×10^6	74.99×10^6	113.49×10^6	714.09	714.03	714.32
13	713.0	59.61×10^6	56.26×10^6	85.15×10^6	714.12	714.08	714.33
14	711.0	170.39×10^6	173.98×10^6	218.38×10^6	712.97	712.99	713.52
15	713.0	253.31×10^6	235.88×10^6	389.68×10^6	714.01	713.95	714.36
16	713.0	99.32×10^6	90.45×10^6	146.97×10^6	714.13	714.08	714.42
17	713.0	99.32×10^6	90.45×10^6	146.97×10^6	714.13	714.08	714.42
18	713.0	253.34×10^6	235.88×10^6	389.68×10^6	714.01	713.96	714.31
19	714.0	43.55×10^6	34.59×10^6	46.65×10^6	714.62	714.56	714.63
20	713.0	234.84×10^6	217.13×10^6	364.21×10^6	714.01	713.97	714.37
21	713.0	141.45×10^6	128.55×10^6	229.94×10^6	714.01	713.95	714.39
22	713.0	99.32×10^6	90.45×10^6	146.97×10^6	714.13	714.08	714.42
23	713.0	234.84×10^6	217.13×10^6	364.21×10^6	714.01	713.97	714.37
24	713.0	234.84×10^6	217.13×10^6	364.21×10^6	714.01	713.97	714.37
*25	-	72.11×10^6	67.37×10^6	101.93×10^6	714.16	714.11	714.37
+26	-	253.31×10^6	235.88×10^6	389.68×10^6	714.01	713.95	714.36
+27	-	253.31×10^6	235.88×10^6	389.68×10^6	714.01	713.95	714.36

*Reach 25 assumed to be similar to Reach 3. +Reach 26 and 27 assumed to be similar to Reach 15.

TABLE 9

COMPUTED PROFILE CHANGES DUE TO CHANGE IN EFFECTIVE LAKE LEVELS

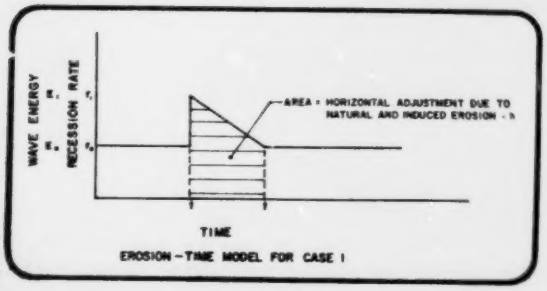
Reach	Slope at $P_{.33}$ "n"(%)	b	c	d	Recorded to Regulated a	Recorded to Regulated h	Unregulated to Regulated a	Unregulated to Regulated h
1	0.7	-	-	-	0.42 ft.	60 ft.	0.46 ft.	66 ft.
2	0.6	-	-	-	0.25 ft.	42 ft.	0.29 ft.	48 ft.
3	1.1	-	-	-	0.21 ft.	19 ft.	0.26 ft.	24 ft.
4	0.6	-	-	-	0.42 ft.	70 ft.	0.46 ft.	77 ft.
5	1.0	-	-	-	0.43 ft	43 ft.	0.45 ft.	45 ft.
6	0.8	-	-	-	0.21 ft.	26 ft.	0.26 ft.	33 ft.
7	0.4	-	-	-	0.24 ft.	60 ft.	0.28 ft.	70 ft.
8	1.0	-	-	-	0.19 ft.	19 ft.	0.27 ft.	27 ft.
9	0.5	-	-	-	0.23 ft.	46 ft.	0.29 ft.	58 ft.
10	0.9	-	-	-	0.21 ft.	23 ft.	0.26 ft.	29 ft.
11	0.7	-	-	-	0.21 ft.	30 ft.	0.26 ft.	37 ft.
12	0.3	-	-	-	0.23 ft.	76 ft.	0.29 ft.	97 ft.
13	0.9	-	-	-	0.21 ft.	23 ft.	0.25 ft.	28 ft.
14	0.3	-	-	-	0.55 ft.	182 ft.	0.53 ft.	177 ft.
15	-	1600	5.5	8	0.35 ft.	41 ft.	0.41 ft.	48 ft.
16	-	250	20.0	8	0.29 ft.	3 ft.	0.34 ft.	3 ft.
17	-	280	20.0	8	0.29 ft.	3 ft.	0.34 ft.	3 ft.
18	-	600	23.0	8	0.35 ft.	7 ft.	0.40 ft.	8 ft.
19	-	150	13.0	9	0.01 ft.	0 ft.	0.07 ft.	0 ft.
20	-	350	18.0	8	0.36 ft.	5 ft.	0.40 ft.	5 ft.
21	-	500	8.0	8	0.38 ft.	12 ft.	0.43 ft.	13 ft.
22	-	450	17.0	8	0.29 ft.	5 ft.	0.34 ft.	6 ft.
23	-	300	18.0	8	0.36 ft.	4 ft.	0.40 ft.	5 ft.
24	-	500	31.0	8	0.36 ft.	5 ft.	0.40 ft.	5 ft.
+25	-	1600	15.0	9	0.21 ft.	13 ft.	0.26 ft.	16 ft.
+26	-	-	-	-	0.35 ft.	41 ft.	0.41 ft.	48 ft.
+27	-	-	-	-	0.35 ft.	41 ft.	0.41 ft.	48 ft.

* The "a" value in reach 25 is assumed to be the same as in reach 3.
+ Reach 26 and 27 assumed to be similar to reach 15.

in the table are the same as defined earlier. The values shown are averages for the reaches. Substantial variations may exist within a reach. Where the horizontal recession of the shoreline is prevented by means of protective structures, the lake bottom seaward of the structure may be expected to degrade as though the profile shift were taking place.

7. TIME REQUIRED TO EFFECT PROFILE ADJUSTMENT. The time required to effect the predicted profile adjustments due to a change in effective lake level may be computed on the basis of three different assumptions where erosion is occurring naturally.

Case 1. Where erosion is occurring naturally along a shoreline, the time required to effect the profile adjustment due to a small change in effective lake level may be estimated by assuming that the vertical profile adjustment



EROSION-TIME MODEL FOR CASE I

"a" will occur during the time "t" that the shoreline recedes (because of the combined effect of induced and natural erosion) by an amount equal to the required horizontal adjustment "h".

In this case the time required would be equal to the required horizontal adjustment divided by the changed average annual rate of erosion as follows:

$$h = \left(\frac{r_0 + r_1}{2}\right) (t_1 - t_0)$$

$$\Delta t = \frac{h}{r_0 \left(1 + \frac{\Delta E}{2E_0}\right)}$$

where r_0 = rate of recession under recorded conditions

E_0 = wave energy causing erosion under recorded conditions

ΔE = change in wave energy causing erosion due to change in lake level.

For example, if h = 30 ft; r_0 = 2 ft/yr; $\frac{\Delta E}{E_0}$ = 0.5; then $\Delta t = \frac{30}{2\left(1 + \frac{0.5}{2}\right)}$ = 12 years. The recession attributable to the change in lake level is then equal to the increase in the rate of recession multiplied by the time over which the increase in rate acts:

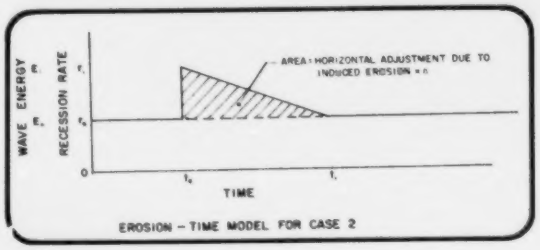
$$\Delta h = \left(\frac{r_0 + \Delta r - r_0}{2}\right) \Delta t = \frac{\Delta r}{2} \frac{h}{r_0 \left(1 + \frac{\Delta E}{2E_0}\right)} =$$

$$\frac{\frac{\Delta E}{2E_0} \quad h}{\left(1 + \frac{\Delta E}{2E_0}\right)}$$

Since $\frac{\Delta E}{E}$ is typically equal to about 0.5 for most reaches: $\Delta h = \frac{0.5}{2} \frac{h}{\left(1 + \frac{0.5}{2}\right)} = 0.2\ h$

That is, for the assumption of Case 1, the loss of land attributable to the change in lake level is about 20% of the amount of the horizontal profile shift.

Case 2. Where erosion is occurring naturally along a shoreline, the time required to effect the profile adjustment due to a small change in effective lake level may also be estimated by assuming that the profile "h" is caused only by the increase in the erosion rate and occurs independently of the natural erosion process.



EROSION – TIME MODEL FOR CASE 2

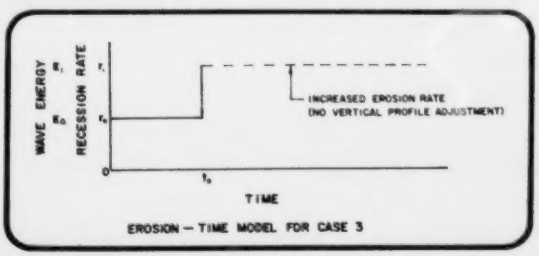
In this case the time required would be equal to the required horizontal adjustment divided by the average increase in the annual rate of erosion as follows:

$$\Delta t = \frac{h}{\frac{r_1 - r_0}{2}} = \frac{h}{\frac{r_0 \ \Delta r}{2 \ r_0}} = \frac{h}{\frac{r_0 \ \Delta E}{2 \ E_0}}$$

For example if h = 30 ft; r_0 = 2 ft/yr; $\frac{\Delta E}{E} = 0.5$; then $\Delta t = \frac{30}{\frac{2}{2} \times 0.5} = 60$ years

For the assumption of Case 2 the loss of land attributable to the change in lake level would be the total amount of the horizontal profile shift.

Case 3. As an upper limiting condition one could assume that the vertical profile shift would occur so slowly that the time required for the profile adjustment would approach infinity.



EROSION – TIME MODEL FOR CASE 3

In this case the recession attributable to the change in lake level would be a constant increase in the existing rate of erosion as equal to $r = r_0 \frac{\Delta E}{E_0}$.

For the case of a naturally eroding shoreline the most probable case is considered to be intermediate between Cases 1 and 2. Although it is not possible to determine the most probable actual case with greater precision, one can propose that shoreline development plans be based on Case 1 (giving the shortest adjustment time) and that damages attributable to Lake regulation be based on Case 2 (attributing to the change in lake level the total amount of the horizontal profile adjustment). The times required to effect the profile adjustments computed as outlined in Case 1 and Case 2 are summarized in Table 10.

TABLE 10

TIME REQUIRED FOR PROFILE ADJUSTMENT

Reach	Case 1		Case 2	
	Recorded to Regulated (Years)	Unregulated to Regulated (Years)	Recorded to Regulated (Years)	Unregulated to Regulated (Years)
1	24	27	134	138
2	22	26	123	126
3	15	17	87	460
4	31	37	182	190
5	29	37	172	167
6	15	20	89	97
7	9	13	50	65
8	45	75	260	312
9	6	11	31	57
10	13	17	74	80
11	22	29	131	138
12	83	171	205	330
13	22	27	116	133
14	19	14	90	166
15	7	8	31	54
16	2	2	8	7
17	2	3	12	11
18	5	6	22	18
19	0	0	0	0
20	5	5	23	21
21	6	7	24	25
22	2	3	11	12
23	3	4	14	16
24	7	7	33	25
*25	10	21	32	29
*26	7	8	31	54
*27	7	8	31	54

* Reach 25 assumed to be similar to reach 3.
* Reach 26 and 27 assumed to be similar to reach 15.
• The adjustment times for reaches 26 and 27 are based on computed historic erosion rates which may be too high. Hence actual adjustment times may be greater.

H. LOSS OF LAND DUE TO EROSION.

The annual rate of land loss due to erosion under recorded conditions was determined by measuring the area between the earliest and the latest shorelines on the shorelines plans and converting this to an annual rate. The loss of land was expressed in terms of square feet per reach per year and also as an average linear rate of landward shoreline recession in feet per year.

The rate of land loss which would occur under unregulated and regulated conditions was derived by computing the average linear rates of shoreline recession during the profile adjustment period for the unregulated and regulated conditions in each reach and multiplying these rates by the actual length of shoreline in each reach. The land losses are expressed in terms of square feet per reach per year. A summary of the above results is included in Table 11.

TABLE 11

AVERAGE ANNUAL RATES OF LAND LOSS

Reach	Length (feet)	Average Recorded Erosion Rate (feet/year)	Recorded Area Loss (feet^2/year)	Unregulated(1) Area Loss (feet^2/year)	Regulated(1) Area Loss (feet^2/year)
1	30,300	2.07	62,719	61,660	76,053
2	19,303	1.55	29,921	29,244	36,579
3	11,676	0.21	2,452	2,393	2,977
4	13,403	1.77	23,724	23,254	28,682
5	16,751	1.24	20,772	20,603	25,042
6	23,538	1.40	32,956	31,776	39,661
7	14,676	5.30	77,785	69,566	91,725
8	9,527	0.36	3,430	3,286	4,144
9	7,357	6.38	46,944	46,018	57,862
10	11,345	1.48	16,741	16,280	20,307
11	11,894	1.11	13,203	12,726	15,937
12	7,460	0.75	5,594	5,483	6,863
13	23,974	0.86	20,618	20,138	25,292
14	9,400	8.54	80,270	79,571	101,708
15	14,319	4.80	68,690	68,247	87,004
16	23,162	1.60	37,060	35,322	46,092
17	5,846	0.98	5,730	5,524	7,132
18	18,870	1.20	22,635	21,700	28,399
19	25,736	0.95	24,459	21,875	25,221
20	6,725	0.75	5,044	4,875	6,422
21	9,060	1.43	12,955	12,366	16,987
22	3,800	1.75	6,650	6,398	8,284
23	7,400	0.99	7,326	7,030	9,324
24	12,766	0.57	7,277	7,148	9,446
25	34,700	1.15	38,900	37,900	56,000
26	33,800	11.12	375,000(2)	348,000(2)	465,000(2)
27	30,300	4.50	136,500(2)	133,000(2)	153,000(2)
		Totals	673,394	649,391	843,143
		Total Acres	15.45	14.90	19.12

(1) Based on Average rate during profile adjustment period.

(2) The validity of these recorded erosion rates is doubtful, hence area losses based on these rates are not included in the totals.

1. TOTAL LOSS OF LAND DUE TO PROFILE ADJUSTMENT. The loss of land associated with the profile adjustment from recorded to regulated and from modified historic to regulated was computed for each reach by multiplying the length of the reach by the appropriate horizontal adjustment. The results are summarized in Table 12. Because of natural erosion, the proportion of this land loss which is attributable to regulation of the Lake level depends on the erosion - time model (Case 1 or Case 2) which is accepted. Case 1 implies that about 20% and Case 2 implies that 100% of the land loss is attributable to regulation.

TABLE 12

TOTAL LAND LOSS DUE TO PROFILE ADJUSTMENT

Reach	Length feet	Recorded to Regulated h feet	Recorded to Regulated Total (feet)^2	Recorded to Regulated Area acres	Unregulated to Regulated h feet	Unregulated to Regulated Total (feet)^2	Unregulated to Regulated Area acres
1	30,300	60	1,818,000	41.73	68	1,999,800	45.90
2	19,303	42	810,726	18.61	48	926,544	21.27
3	11,676	19	221,844	5.09	24	280,224	6.43
4	13,403	70	938,210	21.53	77	1,032,031	23.69
5	16,751	43	720,293	16.53	45	753,795	17.30
6	23,538	26	611,988	14.04	33	776,754	17.83
7	14,676	60	880,560	20.21	70	1,027,320	23.58
8	9,527	19	181,013	4.15	27	257,229	5.90
9	7,357	46	338,422	7.77	58	426,706	9.80
10	11,345	23	260,935	5.99	29	329,005	7.55
11	11,894	30	356,820	8.19	37	440,078	10.10
12	7,460	76	566,960	13.01	97	723,620	16.61
13	23,974	23	551,402	12.65	28	671,272	15.41
14	9,400	182	1,710,800	39.27	177	1,663,800	38.19
15	14,310	41	586,710	13.47	48	686,880	15.77
16	23,162	3	69,486	1.59	3	69,486	1.59
17	5,846	3	17,538	0.40	3	17,538	0.40
18	18,870	7	132,090	3.03	8	150,960	3.46
19	25,736	0	0	0	0	0	0
20	6,725	5	33,625	0.77	5	33,625	0.77
21	9,060	12	108,720	2.49	13	117,780	2.70
22	3,800	5	19,000	0.44	6	22,800	0.52
23	7,400	4	29,600	0.68	5	37,000	0.85
24	12,766	5	63,830	1.46	5	63,830	1.46
25	34,700	25	867,000	19.9	31	1,075,000	24.7
* 26	33,800	41	1,385,000	31.8	48	1,620,000	37.2
* 27	30,300	41	1,245,000	28.6	48	1,455,000	33.4
			Total	273.0			311.8

* Because historic data for these reaches is doubtful, the areas are not included in the totals.

I. VOLUMES OF SOIL MATERIAL GENERATED DUE TO EROSION.

The annual volume of soil material generated by erosion under recorded conditions has been computed by multiplying the average annual land loss area under recorded conditions by the difference in elevation between the surface of the land (top of eroding bank) and the bottom of the adjacent lake which was taken to be elevation 705. The volumes of soil material generated under unregulated and regulated conditions were computed by the same method. The reaches which do not generate new sand by actual bank erosion are not included in the totals in Table 14.

The volumes of eroded soil material have been divided into coarse grained (gravel and sand) and fine grained (silt and clay). The coarse grained particles would form beach material while the fine grained particles would be deposited offshore or would be carried out of the lake. The volumes generated are expressed in terms of tons per reach per year where one cubic yard of sediment is approximately equal to 1.2 tons of sediment. The calculations are summarized in Table 14.

Sediment also enters the south pool of Lake Winnipeg from tributary streams, notably from the Red River. This process of course will not be affected by regulation. The available data indicating the quantity of sediment carried by the Red River is summarized in the following table.

TABLE 13

ANNUAL SUSPENDED SEDIMENT CARRIED BY RED RIVER AS MEASURED AT LOCKPORT

Year	Sediment-tons	Year	Sediment-tons
1962	1.29×10^6	1967	2.65×10^6
1963	1.43 x "	1968	0.98 x "
1964	2.17 x "	1969	3.78 x "
1965	3.85 x "	1970	3.45 x "
1966	3.28 x "		

The mean annual suspended sediment carried by the Red River is 2.65×10^6 tons of which approximately three percent is fine sand. Hence the volume of fine sand (greater than 0.062 mm and less than 0.500 mm) contributed by the Red River to the south pool as measured at Lockport is approximately 80,000 tons per year. The total annual volume of material eroded in the south basin is approximately 10 percent of the mean annual suspended sediment volume contributed by the Red River.

1. TOTAL VOLUMES OF MATERIAL GENERATED DUE TO PROFILE ADJUSTMENT. The volume of material generated due to profile adjustment due to a change from recorded to regulated or from unregulated to regulated condition was computed for each reach by multiplying the total area of land loss due to the corresponding change by the difference in elevation between the land surface and the bottom of the adjacent lake. Additionally the volumes of coarse and fine material generated due to a particular change were computed. The percentages of coarse and fine material for each reach was assumed to be the same as the percentages previously used for the annual volumes of soil material generated due to erosion. The results are summarized in Table 15.

TABLE 14

ANNUAL VOLUMES OF SEDIMENT GENERATED DUE TO EROSION

Reach	Vertical Height (feet)	Fine Grain %	Coarse Grain %	Recorded Condition Total Volume (tons)	Recorded Condition Volume Fine (tons)	Recorded Condition Volume Coarse (tons)	Unregulated Condition[1] Total Volume (tons)	Unregulated Condition[1] Volume Fine (tons)	Unregulated Condition[1] Volume Coarse (tons)	Regulated Condition[1] Total Volume (tons)	Regulated Condition[1] Volume Fine (tons)	Regulated Condition[1] Volume Coarse (tons)
1	14.0	85	15	39,021	33,168	5,853	38,362	32,608	5,754	47,317	40,219	7,098
2	13.0	85	15	17,286	14,693	2,593	16,895	14,360	2,535	21,132	17,962	3,170
3	14.5	85	15	1,580	1,343	237	1,542	1,311	231	1,918	1,630	288
4	14.4	85	15	15,182	12,905	2,277	14,881	12,649	2,232	18,354	15,601	2,753
5	20.0	85	15	18,462	15,693	2,769	18,312	15,565	2,747	22,257	18,918	3,339
6	26.0	85	15	38,076	32,365	5,711	36,715	31,208	5,507	45,826	38,952	6,874
7	20.5	85	15	70,864	60,234	10,630	63,374	53,868	9,506	83,563	71,029	12,534
(2)8	15.2	80	20	2,317	1,854	463	2,220	1,776	444	2,799	2,239	560
9	14.8	80	20	30,876	24,701	6,175	30,266	24,213	6,053	38,056	30,445	7,611
10	15.3	80	20	11,417	9,134	2,283	11,069	8,855	2,214	13,807	11,046	2,761
11	17.0	80	20	9,975	7,980	1,995	9,614	7,691	1,923	12,040	9,632	2,408
12	16.2	80	20	4,027	3,222	805	3,947	3,158	789	4,941	3,953	988
13	16.4	80	20	15,027	12,022	3,005	14,677	11,742	2,935	18,433	14,746	3,687
14	13.5	80	20	48,157	38,526	9,631	47,738	38,190	9,548	61,019	48,815	12,204
(2)15	13.5	5	95	41,210	2,060	39,150	40,944	2,047	38,897	52,197	2,610	49,587
16	28.5	10	90	46,938	4,694	42,244	44,737	4,474	40,263	58,377	5,838	52,539
17	28.3	5	95	7,206	360	6,846	6,947	347	6,600	8,970	448	8,522
(2)18	20.8	5	95	20,923	1,046	19,877	20,058	1,003	19,055	26,251	1,313	24,938
19	21.0	5	95	22,818	1,141	21,677	20,415	1,021	19,394	23,537	1,177	22,360
20	26.0	5	95	5,828	291	5,537	5,633	282	5,351	7,420	371	7,049
21	16.0	5	95	9,212	461	8,751	8,793	440	8,353	12,078	604	11,474
22	24.6	5	95	7,270	363	6,907	6,896	345	6,551	9,056	453	8,603
23	25.7	5	95	8,367	418	7,949	8,029	401	7,628	10,649	532	10,117
24	39.5	5	95	12,774	639	12,135	12,547	627	11,920	16,581	829	15,752
25	40.5	5	95	70,013	3,501	66,512	66,593	3,330	63,263	100,790	5,039	95,751
(3)26	13.5	5	95	224,978	11,249	213,729	208,779	10,439	198,340	278,972	13,949	265,023
(3)27	15.5	5	95	93,680	4,684	88,996	91,613	4,581	87,032	105,389	5,269	100,120
				510,376	277,854	232,522	487,982	268,685	221,297	636,121	338,239	297,882

(1) Average rate during profile adjustment period.

(2) New sand not generated by bank erosion hence these volumes are not included in the totals.

(3) Erosion rates are douhtfull, hence volumes are not included in totals.

TABLE 15

TOTAL VOLUMES OF SOIL MATERIAL GENERATED DUE TO PROFILE ADJUSTMENT

Reach	Vertical Height (feet)	Recorded to Regulated: Total Area (feet)^2	Total Volume (tons)	Volume Fine Grain (tons)	Volume Coarse Grain (tons)	Unregulated to Regulated: Total Area (feet)^2	Total Volume (tons)	Volume Fine Grain (tons)	Volume Coarse Grain (tons)
1	14.0	1,818,000	1,131,087	961,424	169,663	1,999,800	1,244,196	1,057,567	186,629
2	13.0	810,726	468,373	398,117	70,256	926,544	535,283	454,990	80,293
3	14.5	221,844	142,952	121,509	21,443	280,224	180,571	153,485	27,086
4	14.1	938,210	600,359	510,331	90,058	1,032,031	660,428	561,364	99,064
5	20.0	720,293	640,196	544,167	96,029	753,795	669,973	569,477	100,496
6	26.0	611,988	707,115	601,048	106,067	776,754	897,493	762,869	134,624
7	20.5	980,560	801,208	681,877	120,331	1,027,320	935,909	795,523	140,386
8	15.2	181,013	122,271	97,817	24,454	257,229	173,755	139,002	34,751
9	14.8	339,422	222,584	178,067	44,517	426,706	280,649	224,519	56,130
10	15.3	260,935	177,418	141,934	35,484	329,005	223,700	178,960	44,740
11	17.0	356,820	269,570	215,656	53,914	440,078	332,470	265,976	66,494
12	16.2	566,960	408,166	326,533	81,633	723,620	520,949	416,759	104,190
13	16.4	551,402	401,867	321,494	80,373	671,272	489,230	391,384	97,846
14	13.5	1,710,800	1,026,377	821,102	205,275	1,663,800	998,180	798,544	199,636
15	13.5	586,710	351,991	17,600	334,391	686,880	412,087	20,604	391,483
16	28.5	69,486	88,007	8,801	79,206	69,486	88,007	8,801	79,206
17	28.3	17,538	22,057	1,103	20,954	17,538	22,057	1,103	20,954
18	20.8	132,000	122,097	6,105	115,992	150,960	139,540	6,977	132,563
19	21.0	0	0	0	0	0	0	0	0
20	26.0	33,625	38,852	1,943	36,909	33,625	38,852	1,943	36,909
21	16.0	108,720	77,304	3,865	73,439	117,780	83,746	4,187	79,559
22	24.6	19,000	20,771	1,039	19,732	22,800	24,925	1,246	23,679
23	25.7	29,600	33,806	1,690	32,116	37,000	42,258	2,113	40,145
24	30.5	63,830	112,046	5,602	106,444	63,830	112,046	5,603	106,443
25	40.5	431,109	811,899	40,595	771,304	555,200	999,260	49,963	949,297
* 26	13.5	1,385,800	831,397	41,570	789,827	1,622,400	973,343	48,667	924,676
* 27	13.5	1,242,300	855,721	42,786	812,935	1,454,400	1,001,820	50,091	951,729
			8,799,413	6,009,239	2,789,984		10,105,562	6,872,959	3,232,702

* Because erosion rates are doubtful, these volumes are not included in the totals.

CHAPTER 6

SAND MOVEMENT STUDY

A. METHODOLOGY FOR THE SAND MOVEMENT STUDY.

The methodology for the sand movement study involves a brief review of the processes causing sand movement on Lake Winnipeg, an inventory of sand quantities, and an estimate of sand transport rates. Additionally, the effects of the proposed regulation on beaches and transport rates will be assessed. Some consideration of mitigation and enhancement measures is also included.

B. GENERAL PROCESSES.

1. GENERATION OF SAND. On Lake Winnipeg wave energy dissipation at the shoreline is partially reflected as an erosion process. Waves impinging on a sand sufficient profile confine the cutting and filling on the profile to within the sand body. However, on a sand starved profile, wave energy exposes the in-situ soil material when moving the sand parallel or transversely to the shoreline. The wave action erodes the exposed insitu soil and fine grained particles (clay and silt) are transported to deep offshore areas where settling occurs and the coarse grained particles (sand, gravel, cobbles or boulders) remain on or near the shoreline forming a beach material.

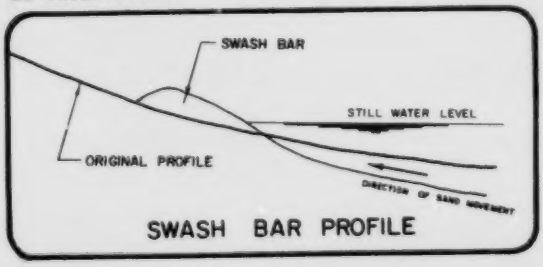
The size and quantity of beach material generated is determined by the type of soil eroded. For example, the lacustrine

clays and clayey tills along the west shoreline yield mainly sand and gravel size material, but the sandy tills along the east shoreline yield sand, gravel, cobble and boulder size material. Additionally, the lacustrine clays and clayey tills along the west shoreline contain approximately 15% beach material, whereas the sandy tills along the east shoreline contain approximately 85% beach material per volume of insitu soil eroded.

The granular beach materials along the east and west shorelines of the lake are derived primarily from the erosion of the land masses along the shorelines. Along the south shoreline the beach material is derived from littoral processes acting along east and west shorelines and, as previously indicated, some contribution is made by the Red River.

2. PROFILES FORMED BY WAVES. The type of waves impinging on a beach is the principal variable controlling the formation of the beach profiles. The change from profile erosion to profile accretion occurs suddenly at a wave steepness of about 0.03. The wave steepness is defined as the deep water wave height divided by the deep water wave length. Long, low waves with a low wave steepness ratio, less than 0.03, build up a beach profile; short, high storm waves with a high wave steepness ratio, greater than 0.03, erode a beach profile. (King 1972)(5).

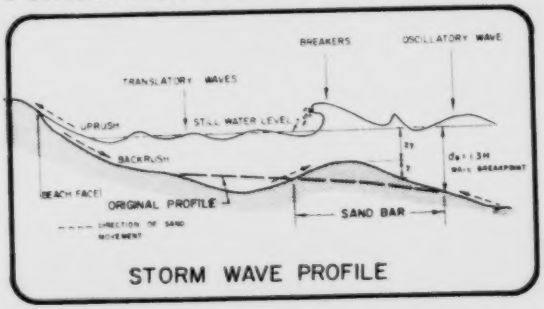
Long, low waves impinging on a beach form a swash bar profile characterized by a swash bar forming at the limit of the wave uprush as shown below.



SWASH BAR PROFILE

The crest height of the swash bar increases with decreasing wave steepness and is independent of other wave parameters. The swash bar will form only if the original gradient of the beach is less than the gradient built up by the swash of the waves. This process is an attempt by the waves to re-establish an equilibrium profile.

Short, high storm waves impinging on a beach produce a profile which is characterized by the formation of an underwater sand bar as illustrated below. The position and height of the sand bar is related to the height of the waves impinging on the beach. The underwater sand bar is formed offshore on the profile at a depth of water just forward of where wave breaking occurs. Waves break when they reach a depth of water which is 1.3 times the wave height. The height of the sand bar formed above the original profile and the depth of water over the sand bar has a constant ratio of 1:2.

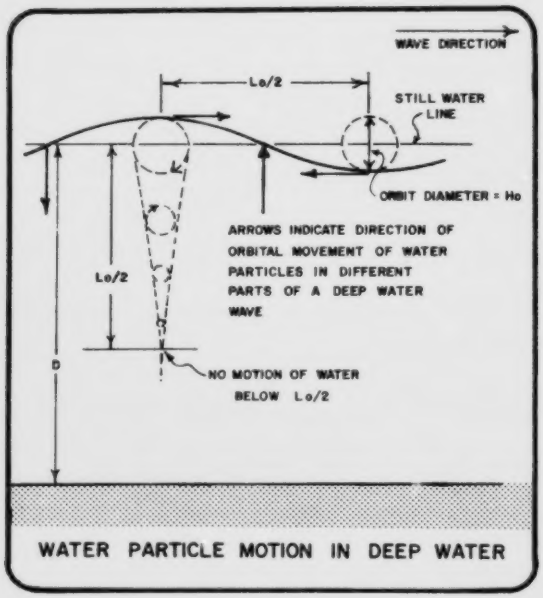


STORM WAVE PROFILE

When more than one predominant storm wave height impinges on a beach, a series of underwater sand bars may be formed on the profile. Underwater sand bars are not formed on sand starved profiles.

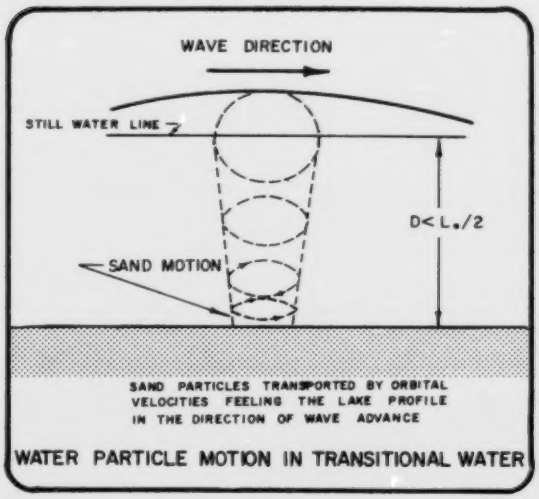
Waves are continuously changing with time and even a wave train of a few minutes duration will contain waves that both erode and build up a profile. Hence a profile is, at best, in dynamic equilibrium. This continual search for an equilibrium profile shape results in sand moving in an onshore, offshore and along shore direction depending on the nature of the waves.

3. SAND TRANSPORT BY WAVES: The water particles comprising a wave travelling in deep water move in nearly closed circular orbits. The orbital velocities decrease exponentially below the surface of the water until at a depth of one-half the wave length there is effectively no orbital motion. This phenomenon is illustrated below.


WAVE DIRECTION
Lo/2
STILL WATER LINE
ORBIT DIAMETER = Ho
ARROWS INDICATE DIRECTION OF ORBITAL MOVEMENT OF WATER PARTICLES IN DIFFERENT PARTS OF A DEEP WATER WAVE
Lo/2
D
NO MOTION OF WATER BELOW Lo/2
WATER PARTICLE MOTION IN DEEP WATER

As a wave approaches a shoreline and the depth of water becomes less than on-half the wave length, the orbital velocities begin to feel the lake bottom. A further decrease in water depth increases the orbital velocities near the profile. When the threshold velocity on the profile for a particular material size is exceeded the orbital velocities transport the material in the direction of wave advance as illustrated in the following sketch. The depth of water at which sand begins to be transported shoreward is dependent on the wave height.

The orbital wave particle motions of long, low waves with a low deep water wave steepness ratio approaching a shoreline perpendicularly transport sand towards the shore up to the swash bar as shown in the illustration "Swash Bar Profile". Sand friction and gravity forces exceed the wave forces at the limit of wave uprush and the sand is deposited forming the swash bar.


WAVE DIRECTION
STILL WATER LINE
D< L./2
SAND MOTION
SAND PARTICLES TRANSPORTED BY ORBITAL VELOCITIES FEELING THE LAKE PROFILE IN THE DIRECTION OF WAVE ADVANCE
WATER PARTICLE MOTION IN TRANSITIONAL WATER

Short, high storm waves with a high deep water wave steepness ratio approaching a shoreline perpendicularly transport sand in two zones. In the zone lakeward of the wave breaking point sand is always transported in the direction of wave advance by the orbital water particle motions up to the wave breaking point as shown in the illustration "Storm Wave Profile".

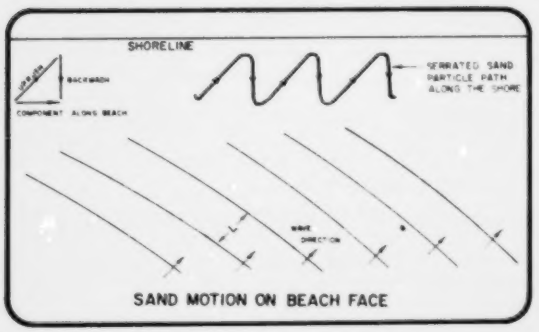
In the zone landward of the wave breaking point sand is generally transported in an offshore direction towards the underwater sand bar as shown in the illustration "Storm Wave Profile" on the previous page. Water which surges forward towards the shore, landward of the wave breaking point, returns to the offshore area carrying sand towards the underwater sand bar. The simultaneous onshore and offshore movements of sand meet just forward of the wave breaking point resulting in the formation of the underwater sand bar. Waves impinging on low lying land as described in the shoreline classification types 1, 2, 3 and 4, run up onto the prairie during periods of high wind setup and severe storm activity. On Lake Winnipeg waves overtopping low lying land build sand and gravel ridges to approximately elevation 720.0.

Theoretically, it is possible, on a mild slope beach, for the translatory waves formed landward of the wave break point to build up a beach at the edge of the waterline; however, on Lake Winnipeg evidence suggests that the profile landward of the wave break point is eroded by short high storm waves.

From the soil and profile surveys conducted, there is clear evidence of the sand transport directions indicated above. The lake bottom is composed of cohesive material with the sand deposits being concentrated in a band along the shorelines. Along the west shoreline the bulk of the sand is at the water's edge. The depth of sand is normally six inches deep 100 feet offshore from the water's edge, and becomes progressively thinner with horizontal distance beyond 100 feet offshore. Sand is not found 600 feet offshore from the water's edge along the west shore.

Along the south and east shorelines where deeper deposits occur, the sand is also concentrated near the shoreline. The soil surveys indicate that when the offshore limit of the sand deposit was encountered on a profile sand deposits beyond this point were not found. The concentration of the sand adjacent to the shoreline is the result of all waves transporting sand towards the shoreline. Additionally, the profile shapes in sand sufficient areas clearly indicate the presence of underwater sand bars landward of the wave break point.

Besides the transverse movement of sand, there is longshore movement of sand. Waves approaching a shoreline at an oblique angle and longshore currents both cause longshore movement of sand. Long, low waves approaching a shoreline at an oblique angle transport sand in a direction which has a direction component parallel to the shore. On the swash bar on the beach face, the uprush and backrush of the oblique waves move sand in a serrated fashion along the shoreline as illustrated in the diagram below.



SAND MOTION ON BEACH FACE

Both the orbital water particle motions and the uprush-backrush of the waves move sand along the shores under low type waves.

Short, high storm waves approaching a shoreline at an oblique angle also move sand with a direction component parallel to the shore outside the wave break point.

The breaking of waves at the break point places sand into suspension and also surges excess water towards the shoreline creating a longshore current. The combination of oblique waves tossing sand forward with a parallel to the shore component and the alongshore current transporting sand in suspension parallel to the shore results in the longshore transport of sand landward of the break point by short high storm waves. Additionally, the uprush and backrush associated with the waves moves sand along the shore.

Under any type of wave conditions the maximum rate of sand movement occurs when the angle between the direction of wave approach and the shoreline is 50 degrees.

The longshore transport phenomena is evident on the lake by the formation of sand spits as evident south of Grand Marais and south of Willow Island. Also, the longshore movement of sand out of an area is evident

along the lake shoreline in the Matlock area. A relationship for the rate of sand movement on sand sufficient profiles has been developed by the U. S. Army Coastal Engineering Research Centre relating the longshore component of deep water wave energy to the littoral transport rate. The relationship as published in "Shore Planning and Design", (1966) (4) is included as Figure 20.

From Lake Winnipeg wave data, the longshore wave energy in reach 7 and the rate of littoral transport north of the Gimli harbour appears to fit the above relationship. From the computed longshore energy and Figure 20 the annual rate of sand transport in reach 7 is approximately 1600 cubic yards per year. The average rate of sand accretion in reach 8 north of the Gimli marine works is approximate ly 1750 cubic yards per year for the period 1898 to 1971. It is believed that the sand transported in reach 7 is intercepted by the marine works in reach 8. On this basis the rate of sand accretion (1750 $yd.^3$/year) in reach 8 agrees closely to the sand transport rate in reach 7 (1600 $yd.^3$/year) derived from Figure 20. Additionally, the longshore wave energy and the rate of erosion in Reach 24 on Elk Island also seem to fit the relationship. From 1916 to 1971 the average rate is 10,650 cubic yards per year. From the 1971, 1972, and 1973 longshore energy computations and Figure 20 the rate of sand transport is 17,000 cubic yards per year. Despite that different time periods are compared in this reach there is reasonable agreement in the quantitites derived from using Figure 20 and the quantities computed from erosion rates. The Figure 20 relationship will be used to estimate the transport rates in the reaches along the shoreline of the Take.

4. SAND TRANSPORT BY WIND. Besides the transport of sand by wave action, winds transport significant volumes of sand. The volume of sand that wind can transport is dependent on the following variables:

a) Wind speed and direction.
b) Sand size.
c) Moisture content of the sand.
d) Height of cliff landward of the beach.
e) Width of beach exposed to wind.

Offshore winds do not transport appreciable volumes of sand, however, onshore winds greater than 11 m.p.h. transport sand which deplete the beaches and build sand dunes landward of the beach on low-lying land. High cliffs landward of a beach generally cause wind deposition of sand at the toe of the cliff. For a particular wind speed the volume of sand transported increases as the moisture content in the sand decreases and the volume transported increases as the grain size of the sand decreases.

Wind velocities in excess of 11 m.p.h. are capable of transporting dry desert sand (.42 mm diameter) in quantitites as indicated in the following table. (Bagnold 1964) (6).

TABLE 16

WEIGHTS OF SAND TRANSPORTED BY WIND

Wind Velocity m.p.h.	Weight - pounds/ hour/foot width of beach
11.0	0
13.4	6
15.7	12
17.9	24
20.2	49
22.4	79
24.6	110
26.9	170
29.1	226
31.4	324
33.6	427
25.8	566

The wind transport mechanism is particularly evident along the south shoreline, at Patricia Beach, Grand Beach, Hillside Beach and on the north side of Victoria Beach by the formation of barrier dunes. It is believed that during periods of low lake levels wind blowing over exposed sand

beaches built sand dunes in these areas. During high lake levels when less beach is exposed the wind mechanism is much less effective in building sand dunes.

C. INVENTORY

1. PROFILES: The profiles on Lake Winnipeg have a distinct change in profile gradient at elevation 713.0. Additionally where the top of the bank is at elevation 721.0 or higher the upper limit of the beach sand on a profile is at elevation 718.0. In some cases where storm ridges and sand dunes occur the beach material may be considered to extend above elevation 718.0. However, for beach use purposes, the beach using public is interested primarily with the band of beach occurring on a profile between elevation 713.0 and elevation 718.0. Profiles surveyed around the perimeter of the lake indicate the following slopes prevailing within this band of beach.

Location	Slope
Along west shoreline	1:10
Along south shoreline	1:20 to 1:40
Along east shoreline	1:20 to 1:40

In the band between elevations 718.0 and 713.0, the median sand grain size on a 1:10 slope is approximately 0.6 millimeters and the median grain size on a 1:20 to 1:40 slope is approximately 0.3 millimeters.

2. SAND VOLUMES. Along the west shoreline in reaches 1 to 14 the sand deposits are concentrated in a narrow band adjacent to the shoreline. The depth of sand adjacent to the shoreline is generally one and one-half feet to four feet deep however larger deposits of up to twelve feet occur at Gimli and on the sand spits south of Willow Island. The sand layer is normally six inches deep 100 feet offshore from the water's edge and becomes progressively thinner with horizontal distance offshore. Sand is not found beyond 600 feet offshore from the water's edge. A distinct interface is present between the sand and the clays or clay tills. The volumes of sand computed at each profile for profiles 000 to 072 consist of all the sand above the clay or clay-till interface at the shoreline profiles.

Along the south and east shoreline, reaches 15 to 27, sand deposits are more extensive. The boundaries for calculating the sand volumes for profiles 073 to 182 are as follows:

- At the shoreline, a vertical boundary where the shore profile intersects elevation 718.0
- A horizontal boundary at elevation 705.0 if the sand depth extends below elevation 705.0 or the sand-clay interface if the interface is above elevation 705.0
- The horizontal distance offshore was limited to 1500 feet from the vertical boundary intersecting elevation 718.0 if the sand extended beyond 1500 feet above elevation 705.0

The measured sand volumes within the boundaries described above are summarized on Figures 19-1 to 19-5.

The largest sand deposits occur along the east shoreline in reaches 15, 18, 21, 22, 23, 24 and 25 where the volumes of sand are of the order of 5000 cubic feet per foot width of beach. In reaches 16, 17, 19 and 20 the sand volumes along the shoreline are generally less than 1000 cubic feet per foot width of beach.

Relative to the east shoreline sand deposits, the volumes of sand along the west shoreline are small. Along most of the west shoreline, the volumes are less than 600 cubic feet per

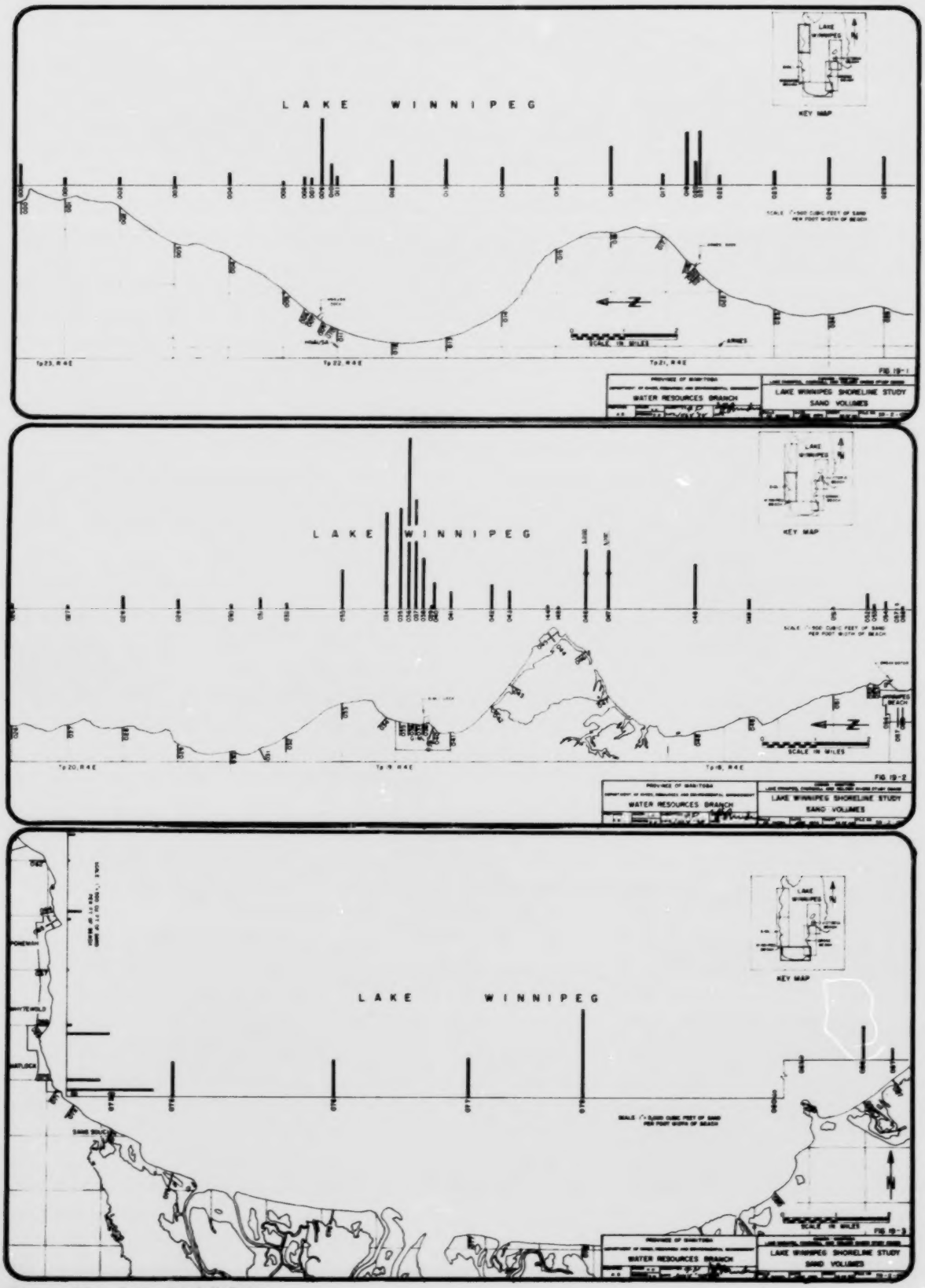


Figure 19 - 1-5 Sand Volumes

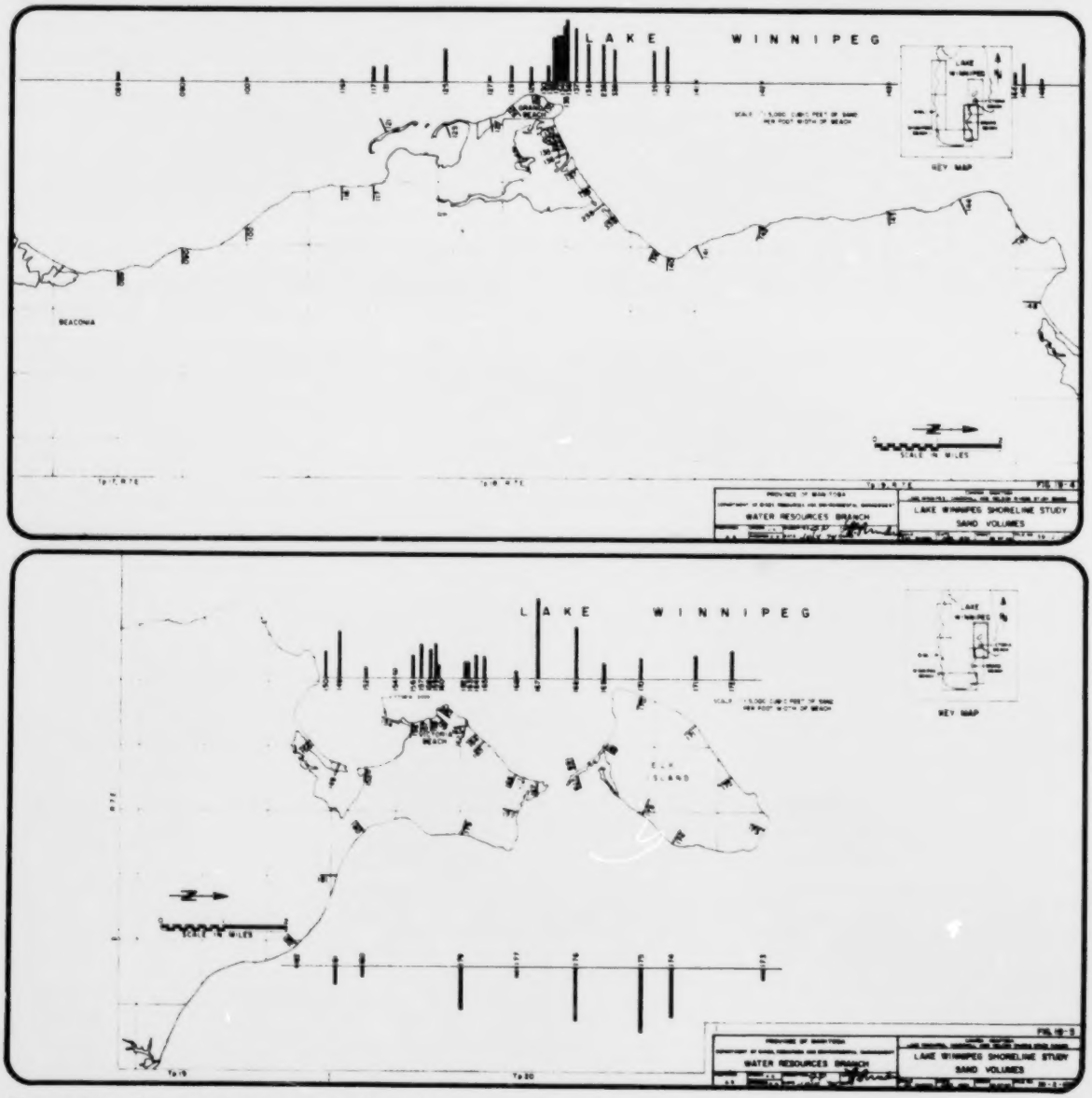


Figure 19 - 1-5 Sand Volumes Continued.

foot width of beach. The only exceptions occur at littoral drift barriers (docks) and on the sand spits south of Willow Island where larger sand volumes are present.

The man-made littoral barriers intercept a portion of the littoral sand drift, accumulating, in some cases, substantial volumes of sand for some distance along the shore on the up-drift side. On the down-drift side the shoreline is sand starved. The average volumes measured on the up-drift side at some of the littoral barriers are shown in Table 17 below.

TABLE 17

SAND VOLUMES AT LITTORAL BARRIERS

Location	Sand Volume $(feet)^3$/foot width	Up-Drift Distance (feet)
Rhausa dock	1000	500
Arnes dock	1000	500
Gimli dock	3000	2500
*Winnipeg Beach breakwater	1500	1200
Victoria Beach dock	0	0

*Volume of sand estimated.

Along the south shoreline in reaches 26 and 27 the volumes of sand are generally in excess of 5000 cubic feet per foot width of beach and the sand deposits are concentrated mostly to the west of the Red River.

3. SAND TRANSPORT. Estimation of current sand transport rates under recorded conditions was performed utilizing the relationship published by the U. S. Army Coastal Engineering Research Centre (Figure 20). The annual longshore deep water wave energy component (defined as E_3) was computed from the 1971, 1972 and 1973 wave climate measurements. The mean net annual longshore energy is the difference between the northerly and southerly total longshore energy reduced to an annual value. The mean net annual longshore energy was then computed by averaging the longshore energies for the three year period in each reach. Wave refraction at the shoreline was ignored since almost all the reaches have a 180 degree wave approach. The rate of longshore drift was determined from Figure 20 in each reach using the mean net annual longshore energy. The predominant direction of littoral drift was considered to be in the direction of the excess net longshore wave energy. The northerly and southerly 3-year longshore energy, mean net annual longshore wave energy, the calculated transport rate, and the predominant direction of sand drift are summarized for each reach in Table 18 and on Figure 21.

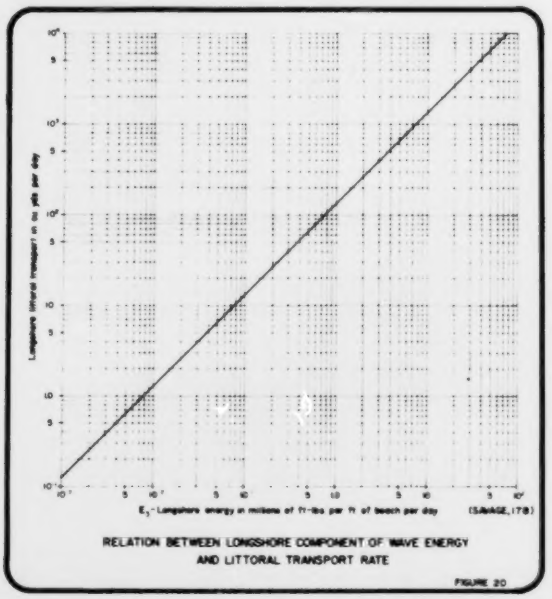


Figure 20 Wave Energy Vs Littoral Transport

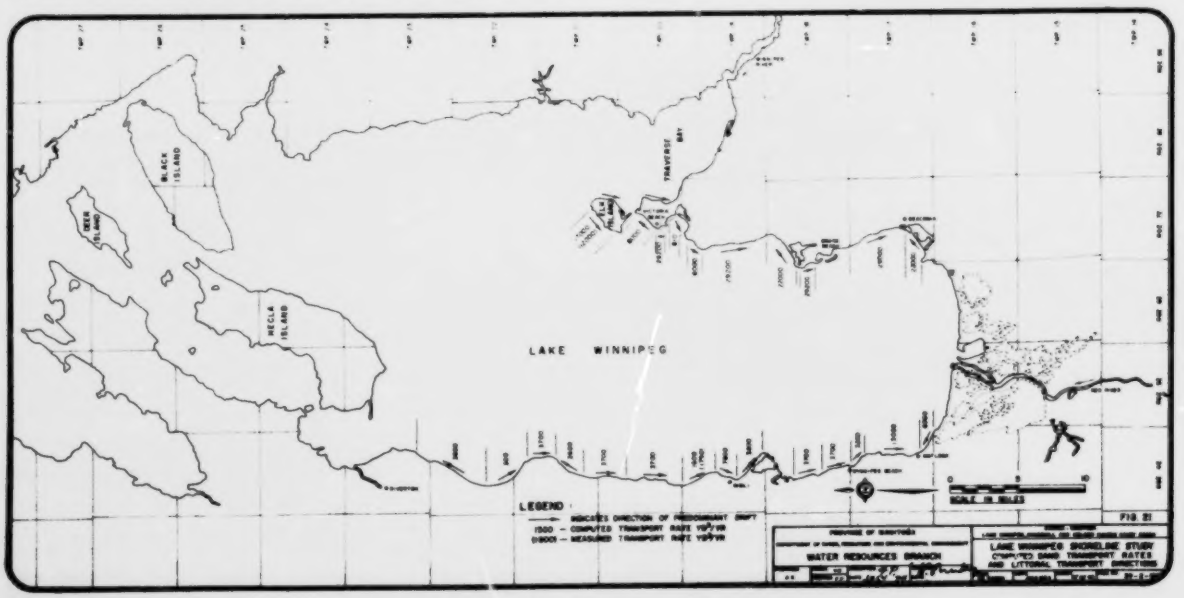


Figure 21 Computed Sand Transport Rates And Littoral Transport Directions

TABLE 18

COMPUTED LONGSHORE ENERGIES, SAND TRANSPORT RATES AND DRIFT DIRECTIONS

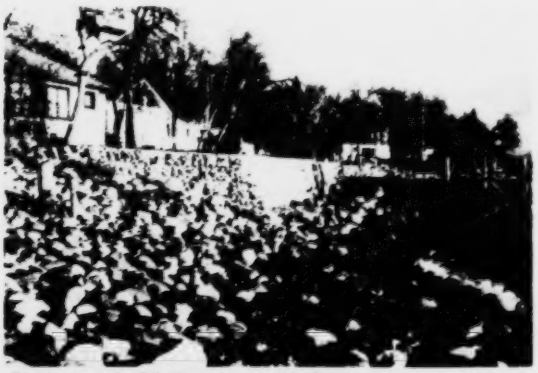
Reach	Northerly Three-Year Wave Energy x 10^6 (ft.-lbs./ ft.)	Southerly Three-Year Wave Energy x 10^6 (ft.-lbs./ ft.)	Mean Net Annual Wave Energy x 10^6 (ft.-lbs./ ft.)	Calculated Transport Rate ($yds.^3$/yr.)	Predominant Drift Direction
1	357.1	273.1	28.0	5,600	South
2	231.5	238.8	2.4	500	South
3	274.7	352.5	29.2	5,700	South
4	357.1	273.1	28.0	5,600	South
5	274.7	352.5	29.4	5,700	South
6	274.7	352.5	29.4	5,700	South
7	231.6	268.7	12.4	1,600	South
8	104.6	279.1	58.2	7,800	South
9	163.7	238.8	25.0	3,100	South
10	274.7	352.5	29.2	5,700	South
11	274.7	352.5	29.2	5,700	South
12	163.7	238.8	25.0	3,200	South
13	50.1	352.5	100.8	13,000	South
14	187.0	45.8	47.6	6,000	North
15	625.8	96.4	176.4	22,000	North
16	357.1	1048.5	230.3	29,200	South
17	357.1	1048.5	230.3	29,200	South
18	625.8	96.4	176.3	22,000	North
19	357.1	1048.5	230.3	29,200	South
20	357.8	164.6	64.3	8,000	North
21	144.6	164.6	6.6	810	South
22	357.1	1048.5	230.3	29,200	South
23	357.8	164.6	64.3	8,000	North
24	357.5	753.8	132.0	16,600	South
25 *					
26 *					
27 *					

* Calculations were not performed for reaches 25, 26, and 27.

The computed rates of sand transport indicate the sand quantity which may be transported on the basis of the assumptions made. Annual wave energy variations or insufficient sand supplies may result in lower or higher actual volumes of sand transported per year in a reach.

The computed rates of sand transport indicate the sand quantity which may be transported on the basis of the assumptions made. Annual wave energy variations or insufficient sand supplies may result in lower or higher actual volumes of sand transported per year in a reach. On the basis of a simplified model the table of longshore energies and sand transport rates was prepared to indicate the general order of magnitude of sand transport rates. Despite the correlations in reach 7 and reach 24 fit the relationship in Figure 20, the values for the rates of sand transport are approximate.

In reaches 14, 15, 18 and 21 the direction of computed sand transport conflict with field observation. Possibly the sand transport rates may also be in error. In reaches 1 to 13 the general computed order of magnitude and the computed direction of sand transport are confirmed by field observation. However, in reaches 16 and 17 the rate of sand transport as derived from Figure 20 appears to be too large. In the reaches where the computed sand transport rate greatly exceeds the sand generated by erosion the beaches are in a sand starved condition. See Photograph 19 of the Matlock area in reach 13 where shoreline erosion is controlled artificially. The transport rate in reach 24 is of the same order of magnitude as in reach 13, however the sand generated in reach 24 balances with the rate of sand transport and the beach is not sand starved. See Photograph 20 in reach 24.



Photograph 19 Beach in Matlock Area in Reach 13. New sand is not generated by erosion.

Photograph 20 Beach on Elk Island in Reach 24. Eroding sandy cliffs supply the beach sand.

D. EFFECTS OF REGULATION ON PROFILES.

The profiles will suffer a loss in beach width until a new profile equilibrium is established. The band of beach between elevations 718.0 and 713.0 will be reduced by 10 percent for each 0.5 foot rise in water level over the recorded long term mean

elevation of 713.2. At the 50 percent less than point of the lake stage-duration curve, the regulated water levels will be from 0.5 feet to 1.5 feet higher during the open-water season. Therefore the higher water levels will result in a 10 to 30 percent reduction in beach width under regulation.

The portion of the profile below elevation 713.0, established by long term processes, will not be affected except for a slow horizontal adjustment as a new profile equilibrium is effected.

E. EFFECTS OF REGULATION ON SAND VOLUMES AND SAND TRANSPORT.

Sand volumes in embayments such as reach 8, reach 26, reach 15, reach 18, and reach 21 will not be reduced by regulation. Adequate sand volumes are present in these reaches to establish new profile equilibriums.

The band of sand presently concentrated adjacent to the shoreline will not be affected. The change to regulated water levels will not change the wave action causing the concentration of sand at the shoreline, hence the sand will remain concentrated adjacent to the shoreline.

Under regulated water levels more wave energy will impinge on the beach above the threshold elevation. An increase in wave energy impinging on the shoreline will reflect in an increased transport rate on eroding shorelines. However, the increase in energy on the shoreline will also increase the rate of sand generation. The increased sand transport rate is offset by the increased sand generation rate. Hence the net volume of sand on a beach will likely remain constant.

CHAPTER 7

ICE EFFECTS STUDY

A. METHODOLOGY FOR ICE EFFECTS STUDY.

The methodology for evaluating the effect of regulation on ice effects involved a review of general lake ice processes, an evaluation of the effects of regulation using analytical computations and a survey of historical damages by interviewing older lake shore residents.

B. GENERAL LAKE ICE PROCESSES

Dr. Newbury (1972) (7) has prepared a description of general ice processes on a freshwater lake at the latitude of the southern portion of Lake Winnipeg from which the following sections have been abstracted.

Inland lakes undergo three distinct periods associated with sheet ice formation: (1) the fall cooling or freeze up period; (2) the ice growth or midwinter period; and (3) the ice melting or break-up period.

1. THE FALL COOLING PERIOD. A typical freshwater lake undergoes cooling in two distinct stages. The initial stage of cooling is gradual as the lake surface temperature approaches 39° F and the maximum density condition of freshwater is reached. During this period, convective mixing occurs easily and the surface layers of water are continuously replaced by warmer underlying water. This process is known as the Fall "turnover".

The second stage of more rapid cooling occurs after the lake has become fully mixed and is isothermal at 39° F. Further cooling depresses the surface layer temperature below 39° F, and as it is now less dense than the underlying water, convective mixing does not occur. As a result, the surface layers are rapidly cooled to the freezing point.

Initial ice formation usually occurs over shallow areas around the lake boundary where the quantity of heat stored below the surface is limited. The process of ice formation rapidly moves inward from the boundary areas as the surface layers of deeper areas are stratified and cooled.

2. THE MIDWINTER ICE GROWTH PERIOD.

(a) Growth Rates. Following the formation of first ice and the freeze over, thickening of the ice cover downward is rapid. As shown in Figure A, the rate of heat loss through the cover is proportional to the temperature gradient between the ice-water interface and the ice-air interface. If the air temperatures are moderately low and the cover thin, the gradient is high and the cover thickens rapidly (1 inch per day for example).

(b) Insulating Effect. As the cover thickens, however, the heat transfer gradient decreases and the growth rate slows as shown in Figure B. This is partially compensated for by lower air temperatures as the winter progresses, but in general, the rate of ice thickening decreases with time until a maximum ice thickness of two to four feet is developed by late February. A rate of thickening of one-half inch per week is normal for this period.

Snow accumulation on the ice surface further reduces the temperature gradient through the ice sheet as the thermal conductivity of snow is only 1/10th that of ice. The surface temperature of an ice cover under 6 inches of snow approaches 32° F as shown in Figure C.

If the snow cover becomes excessive relative to the ice thickness, the weight of snow will depress the cover and surface flooding takes place through cracks. During years of heavy snowfall, it is common to have a continuous layer of snow and ice slush on the cover surface throughout the winter.

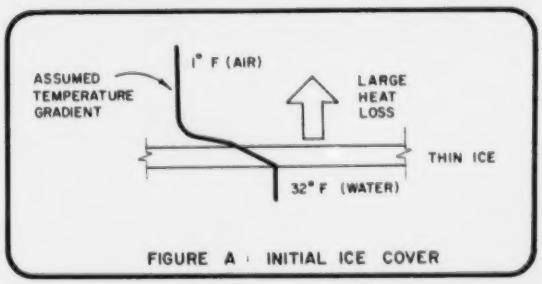


FIGURE A : INITIAL ICE COVER

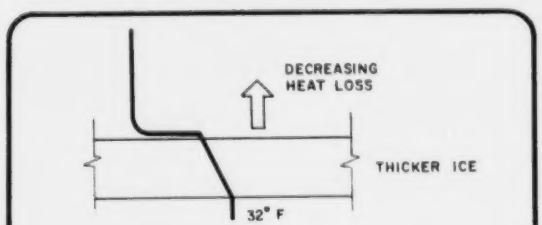


FIGURE B : EARLY WINTER ICE COVER

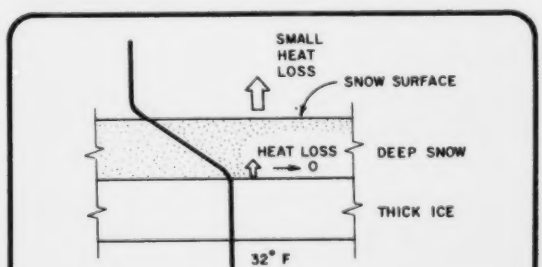


FIGURE C : MIDWINTER ICE COVER

TEMPERATURE GRADIENTS FOR HEAT LOSS AT DIFFERENT STAGES OF SHEET ICE GROWTH

(after Williams, 1968)

(c) Thermal Ice Movements. During the greater part of the ice thickening period when a snow cover is present, the mean ice cover temperature does not fluctuate significantly and little thermal expansion or contraction takes place. During this period, only vertical movements corresponding to water level changes occur.

However, during the early period of ice thickening before a snow cover has accumulated, temperature fluctuations in the cover are substantial and the cover expands and contracts with each daily temperature cycle. As a result, onshore ice shoves take place and the thin cover readily buckles into pressure ridges. There is usually a net onshore movement of ice during this period as fresh water freezes in cracks formed by the contraction of the ice sheet.

3. THE SPRING BREAK UP PERIOD. The spring break up period begins in late March as a net energy gain occurs at the air-snow interface.

(a) Border Melting. As snowmelt begins, water from terrestrial areas adjacent to the lakeshore begins to accumulate along the lake boundaries and at the mouths of inflowing streams. The runoff further darkens the shoreline areas and melting is accelerated around the ice margin. Meltwater on the interior of the ice sheet tends to accumulate and drain through the cover in a series of drainage holes usually coincident with thermal cracks.

(b) Ice Shoves. When the snow cover has melted and a competent cover still exists, diurnal temperature fluctuations again produce thermal expansion and contraction of the ice sheet. Maximum onshore ice thrusts usually occur during this period as the temperature of the cover rises and buckling is suppressed by the greater thickness of the cover.

(c) Ice Piling. As melting of the cover progresses, the shoreline areas usually become ice free leaving the main body of the cover to float freely in the lake. At this stage, expansion and contraction of the cover do not effect the shoreline but ice piling may occur as strong winds drive the cover onshore. The texture of the cover developed during the winter is significant in this process. Melting through the cover occurs first on the planes of impurities that developed around vertical ice agglomerations. As a result, the rotting cover breaks up into a series of verticle ice columns and the cover deforms easily under a wind stress and readily piles onshore. At this stage, the cover is referred to as being "candled".

(d) Final Melting and Stratification. The melting through of the cover on impurity planes further darkens the ice surface and final melting takes place rapidly. Following the ice melt, the surface layers of water are heated and re-stratified. If strong winds occur during the short isothermal period of the lake, a second turnover may occur. There is normally not enough time or temperature gradient for the strong convective currents formed during the Fall turnover period to develop.

C. ICE DAMAGE

From the proceeding description of general ice processes, it is apparent that ice damage on Lake Winnipeg may occur during three periods:

(a) November-December Freeze up Period: by onshore ice shove due to expansion during the late Fall period of pre-snowfall ice cover growth:

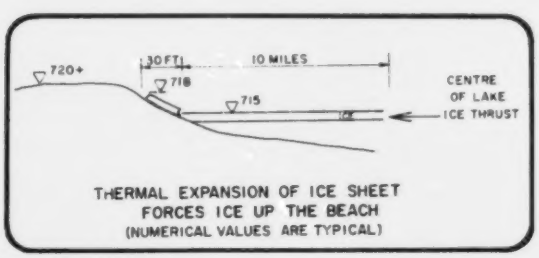
(b) Early April Period: by onshore ice shove due to expansion during the early

melting period following the melting of the snow cover;

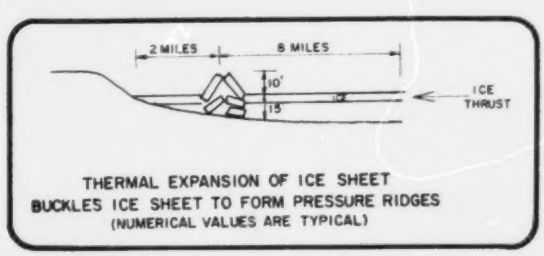
(c) Late April Break up Period: by onshore ice piling that occurs with strong winds during the late break up candled ice stage of melting.

Excessive lateral movement of the ice sheet during the above periods may shift beach material and destroy shoreline vegetation and structures in the movement zone. Damage to submerged structures such as piers, footings, docks, etc., due to vertical movements of the ice sheet corresponding to winter water level fluctuations, may also occur.

1. ICE SHOVE DAMAGE DUE TO THERMAL E[illegible]
Onshore ice shoves due to thermal exp[illegible] take place when the ice cover is [illegible]. Thrusts exerted by the sheet are relatively large and may approach the crushing strength of ice (300 psi at 30° F) when the cover is constrained. Normally these forces are not developed because the ice expands by riding up on the beach or because the ice buckles offshore to form ice pressure ridges as illustrated below.



THERMAL EXPANSION OF ICE SHEET
FORCES ICE UP THE BEACH
(NUMERICAL VALUES ARE TYPICAL)



THERMAL EXPANSION OF ICE SHEET
BUCKLES ICE SHEET TO FORM PRESSURE RIDGES
(NUMERICAL VALUES ARE TYPICAL)

The margin of beach required to accommodate the required expansion depends on several factors listed below:

(a) Maximum temperature fluctuations of the ice sheet

November-December Period: 1° F to 32° F: 31° F

Early April Period: 10° F to 32° F: 22° F

The maximum temperature fluctuation of the ice sheet would occur between the mean minimum December temperature of 1° F and 32° F, the maximum ice surface temperature following the first snowfall. The lesser Spring temperature fluctuation occurs between a mean minimum late March temperature of 10° F and the melting point.

(b) Coefficient of linear expansion
Mean Value: 30×10^{-6} per degree F

(c) Incidence of pressure ridges.
When the cover is relatively thin in the early freeze up period buckling occurs along lines typically as shown in Figure 22. These lines of buckling tend to remain active throughout the winter and provide relief during the early April ice shove period as well. The buckling occurs because the ice is restrained from sliding up the beach, because the ice is frozen to the beach, or beacause it is pushing against a steep bank.

(d) Width of ice sheet. On the basis of these factors and assuming that the mean ice temperature is equal to the mean of the air temperature and the water temperature (32° F) the potential thermal expansion of the ice sheet toward each shoreline was computed as shown in Table 19 below.

TABLE 19

EXPANSION OF ICE SHEET TOWARD EACH SHORELINE

Direction	Width of Ice Sheet	Expansion of Ice Sheet Dec.	Expansion of Ice Sheet April
Gimli-Grand Beach	16 miles	20 feet	14 feet
Unausa-Black River	26 miles	32 feet	23 feet
Hecla Island-Red River	42 miles	52 feet	37 feet

These distances represent the width of beach above the ice level required to permit expansion of the ice without damage to vegetation or shore structures if offshore buckling of the ice sheet does not occur. The vertical rise associated with these horizontal movements depends on the beach slope above the ice level. For a typical slope of 10% for the east and west shores, a rise of 2 to 3 feet would be associated with a horizontal movement of 20 to 30 feet. On the south shore with typical slopes of 5%, a rise of 2 1/2 feet would be associated with a horizontal movement of 50 feet.

Since the horizontal and vertical distances required to accommodate the ice expansion are generally available along the shorelines and since the maximum expansion does not generally develop because of the formation of offshore ice pressure ridges, ice shove damage, except in the case of lightly constructed offshore structure, is not significant on Lake Winnipeg.

Regulation of the level of the lake would affect the position of the ice margin in December and April and thus the amount of beach available to permit expansion of the ice sheet. It is only at the higher levels (when the available beach is narrowest) that ice shove damage may be expected. The following Table 20 lists the lake levels which may be equalled on the average once in 20, 10 and 2 years for the months of November, December, April and May for recorded, unregulated and regulated conditions.

TABLE 20

LAKE LEVELS DURING ICE SHOVE PERIOD EQUALLED ONCE IN 20, 10 and 2 YEARS.

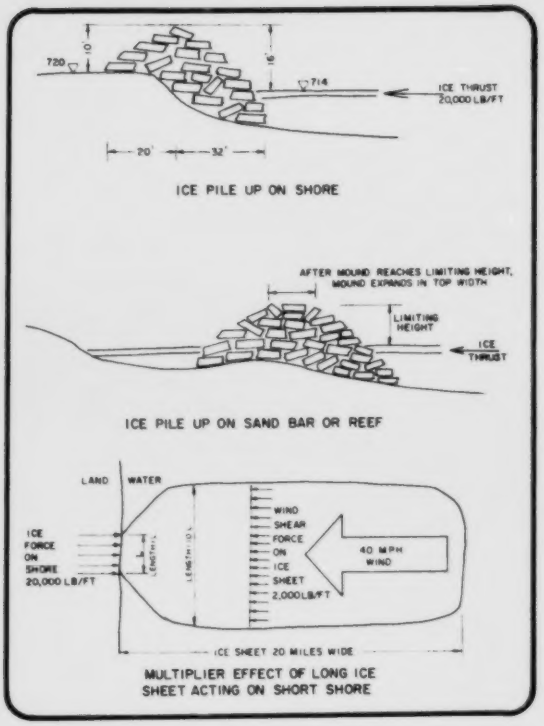
(Add 710.0 to obtain Geodetic elevation)

Conditions	November			December			April			May		
Recorded	5.7	4.7	2.9	5.5	4.7	2.9	5.0	4.3	2.8	5.5	4.8	3.1
Unregulated	5.1	4.9	3.0	5.0	4.9	3.0	5.5	5.0	3.5	5.8	5.2	3.6
Regulated	5.0	5.0	4.6	5.0	5.0	4.4	4.9	4.7	3.9	5.1	5.0	4.0

It should be noted that there is little change in the higher levels that are of interest. Inasmuch as ice shove damage may be expected only at higher lake levels and regulation will cause a minor change in the high lake levels, regulation may be expected to cause a minor change in ice shove damage. The total effect of regulation on ice shove damage would be of very little significance. The data is inadequate to indicate whether any change would increase or decrease damage.

2. ICE PILING DAMAGE.

Lateral shifting of the ice cover under wind stress occurs during the short period of about two weeks or late break up after the ice has melted around the shoreline but before the offshore ice has disintegrated. At this stage the ice cover is melted through and candled; it possesses little vertical shear strength, and is easily broken up into ice pans or rafts. The ice pans may be pushed a short distance up the beach. However, as soon as the ice encounters appreciable resistance due to bottom friction on the beach surface or due to the presence of a structure, the ice piles up into a mound. The mound reaches a certain critical height after which the mound increases in width rather than in height. These effects are illustrated on the following page.



The wind force pushing the ice toward the shore can be computed according to the following formula:

$F_w = 0.06\ U_w^2 \times W$

F_w = wind force (lb/ft)

U_w = wind speed (miles/hr)

W = width of ice sheet over which wind acts (miles)

[The width of the ice sheet is measured perpendicular to the shoreline and the length parallel to the shoreline].

Maximum wind shear forces to be expected along a Lake Winnipeg shoreline, as shown in Table 21, would be roughly 2000 lbs. per lineal foot of ice sheet. At exposed structures and points of land, the forces exerted by the ice sheet on the shoreline could be several times as great as the wind shear forces because the length of ice sheet acted by the wind may be greater than the length of shoreline acted by the ice sheet. For example, if the wind acts on an ice sheet 1000 feet long and the ice sheet pushes against a structure 100 feet long, the ice sheet pushes against a structure 100 feet long, the ice force per unit length of structure would be ten times the wind force per unit length of ice sheet as illustrated below. This multiplier effect is needed to explain ice piling damage. However, the multiplier effect is limited by the structural strength of the ice sheet.

TABLE 21

Wind Shear Force on Ice Sheet

Wind Speed Miles/hour	Width of Ice Miles	Wind Force lbs/ft
20	1	24
	10	240
	20	480
40	1	96
	10	960
	20	1920

If the ice sheet is pushed up a gently sloping shoreline in a relatively intact condition, the maximum distance the ice will travel may be estimated from the following formula:

$F_w = DT\ \gamma \tan \phi$

$$D = \frac{F_w}{T\ \gamma \tan \phi}$$

where F_w = wind shear force (lbs/ft)

D = distance ice travels on shore (ft)

T = ice sheet thickness (ft)

γ = unit weight of ice (lb/ft^3)

$\tan \phi$ = coefficient of friction of ice on beach

The coefficient of friction of ice on the beach may be taken equal to the coefficient of friction of sand on sand inasmuch as the beaches are free of snow during the ice pile up season and the sand particles embed themselves in the overlying ice sheet. Using typical values in the following ice travel distance onshore is:

F_w = 2000 lb/ft, T = 2 ft.,

γ = 62.4 x 0.9 lb/ft^3 , tan ϕ = 1/2,

$$D = \frac{2000}{2 \times 62.4 \times 0.9 \times 0.5} = 36 \text{ feet}$$

This movement in the case of Lake Winnipeg is approximately equal to the ice shove distances due to thermal expansion. Hence regulation of the lake may be expected to have no significant effect on damage from this source as well. The ice sheet may of course buckle and pile up before it pushes this far.

Allen (1970) (8) has presented the following formula for computing the height to which broken ice will mound up:

$$h = \sqrt{\frac{2\ pT}{\gamma(1 + \frac{\tan \phi}{\tan \beta})}}$$

h = height of ice mount (ft)

p = compressive stress in ice sheet (lb/ft^2)

T = thickness of ice sheet (ft)

pT = ice thrust (lb/ft)

γ = unit weight of broken ice in mound (lb/ft^3)

tan ϕ = coefficient of internal friction of ice in mound

β = slope angle of ice mound

Substituting typical values:

pT = 2000 lb/ft

γ = 62.4 x 0.9 x 0.7 = 39 lb/ft^3
(assume ice mound has 30% voids)

tan ϕ = 0.5 (this value is a guess, calculation is not sensitive to value of tan ϕ)

tan β = 0.5 (average value taken range is from 0.3 to 1.0)

$$h = \sqrt{\frac{2 \times 2000}{39\ 1 + \frac{.5}{.5}}} = 7.2 \text{ feet.}$$

Mounds to a height of 15 feet or more were observed along the Lake Winnipeg shoreline in the spring of 1973. This process would require a force equal to four times the maximum probable wind force, or alternately that the wind act on an ice sheet four times as long as the resisting shoreline or structure. The latter explanation is the more likely.

The effect of regulation of the lake on ice piling may be evaluated by considering three cases:

(a) ice piling against a vertical face;
(b) ice pile up on the beach;
(c) ice grounding on an offshore bar.

Where ice is pushed against a vertical face, such as a pier, and the depth of water at the pier is less than about 15 feet, the ice will pile up to a height above the water surface approximately as given by the Allen formula. A change in lake level will cause an equal change in the top elevation of the mound. Since regulation causes a slight reduction in the maximum lake levels during the ice piling period, it may be expected to cause a slight reduction in the top elevation of the mound

and, therefore, a slight reduction in damage from this source.

Where the ice sheet runs aground on a beach and the ice piles up into a mound, the change in lake level would cause a corresponding change in the horizontal position of the ice mound. Since regulation causes a slight reduction in maximum ice levels during the ice pile up period, it may be expected to cause the ice to pile up slightly further offshore and therefore cause a slight reduction in damage.

It can be shown that the depth of water over an offshore sand bar is slightly less than the height of wave forming the sand bar. It follows then that for a typical wave height of 3 feet and a typical ice thickness of 3 feet on Lake Winnipeg, the ice will tend to ground on sand bars if the water level at the time of formation of the bars is the same as that during the ice pile up period in the following spring. If the water level rises over winter the ice will tend to over-ride the bars and pile up on the shore, whereas if the water level falls over the winter the ice will have an increased tendency to ground and pile up on offshore bars. Regulation will typically cause a drop in water level over the winter and thus tend to cause the ice to ground and pile up harmlessly on offshore bars where such bars exist.

The effect of changing water levels on the location of ice pile up mounds was clearly observed during the spring of 1973 and 1974. In the spring of 1973 the lake level was down to elevation 714 following four summers with water levels of about elevation 716. Extensive offshore ice pile up was observed in spring 1973. See Photograph 21. During the winter of 1973-74 the lake level rose from elevation 714 to elevation 716. In Spring 1974 ice pile up on offshore bars was much less marked, and ice pile up on the beach was much more pronounced. See Photograph 22 below.

Photograph 21 Offshore ice pile-up near line 067 in 1973. Note lack of damage to wood palisade.

Photograph 22 Onshore ice pile-up damaging wood palisade in Spring 1974 near line 070.

Damage due to ice pile up in 1974 was minimal. This was because only one factor - a high lake level - was present. The other factors such as strong onshore winds were absent.

D. FIELD DATA FROM LAKE WINNIPEG

Eight men who have lived near the shore of Lake Winnipeg and have been associated with the lake as fisherman, contractors or boat operators for periods of 20 to 60 years were interviewed to determine the nature and frequency of ice damage. Four men were from the east shore and four men from the west shore. The results of the interviews may be summarized as follows:

1. Any damage that might occur would occur in spring due to ice pile up under wind action. No damage due to ice shove was reported.

2. Damage due to ice pile up was not known on the east shore. The men said that this was because the land fronting the shoreline was too high. Ice does pile up, but it does not pile up high enough or near enough to the shore to damage structures or trees. The Victoria Beach pier is strong enough to resist ice action.

3. Damage due to ice pile up is known on the west shore opposite low lying land. Typically, a man might be able to recall one or two instances when ice pile up had damaged a cottage or other building located on low lying land very near to the lake. Sometimes the ice damage was believed to have been associated with high lake levels. The impression gained from the interviews was that the frequency of damage due to ice pile up was of the order of once in a lifetime, and depended on a freak combination of circumstances.

In explanation of the lack of damage due to ice expansion it may be noted that local people recognize the severity of wave action and ice action along the shoreline. They do not normally construct boat houses, boat ramps or light docks along the shore. Where boat ramps or cat walks are constructed they are usually removed in fall. The lack of the ability to utilize such structures is not looked upon as a "damage". Additionally, offshore ice pressure ridges develop in early winter and apparently largely relieve ice shove forces.

One case history of damage is reported to illustrate the phenomenon of ice pile up. On May 5, 1965, ice pile up destroyed a boathouse on the west shore. The boathouse was located near line 012 in NW 9-22-4E. (See Figure 22 for location of lines). Photographs 23 and 24, a shore profile, the approximate location of the house and the ice elevation are shown below.

An ice house 300 feet south of the boathouse was not damaged, probably because the owner used a large crawler tractor to

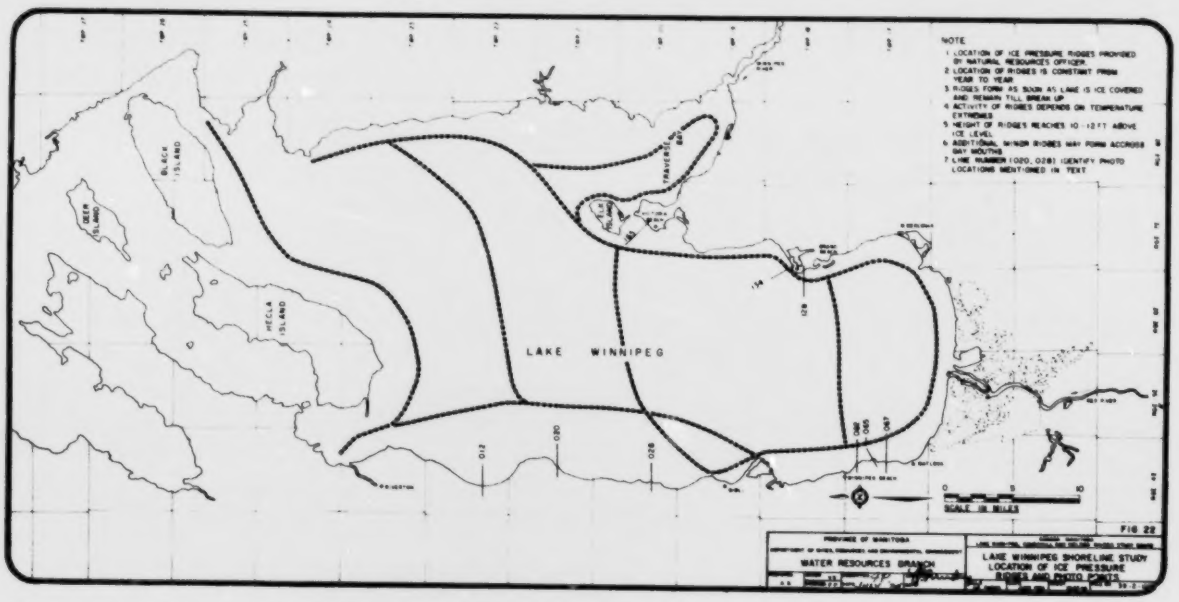
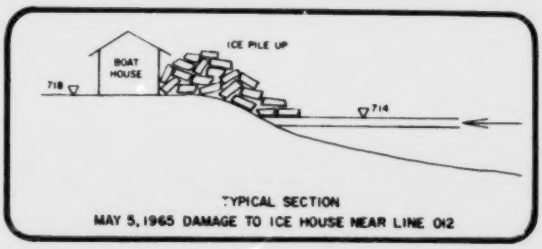


Figure 22. Location of Ice Pressure Ridges and Photo Points.

Photograph 23 Ice pile-up destroying boathouse.

Photograph 24 Ice Pile-up near boat house.



break up the ice pans on the beach so that the ice would pile up further down the beach. This ice house is still intact. The owner states that this is the only damage he has experienced in about 25 years. Ice pile up during all other years was much less than in 1965. The lake level at the time of the damage was about elevation 714 and winds from the easterly sector reached about 35 m.p.h. The following year the lake level was about elevation 716 and winds from the easterly sector reached speeds of about 20 m.p.h. Records indicate that a wind in the range of 25 to 31 m.p.h. from the east-north-east to east-south-east sector during the first two weeks in May may be expected about once in 3 years.

Photograph 25 shows a cottage near line 062 which is reported to have suffered ice damage in one spring several years ago. Photograph 26 shows a frame pump house on the beach near line 028 which was constructed in 1938 and has not suffered any ice damage to date. Photograph 27 shows ice piled up to a height of 15 feet at an abandoned dock near line 128 at Grand Marais. Note the two-foot diameter boulders included in the mound.

Photographs 28 shows ice pile up on the Arnes dock at line 020 to a height of 15 feet above ice level and damage to dock by uplift. Photograph 29 shows ice piled up offshore near line 165 at Victoria Beach. Photograph 30 shows large boulders pushed up the beach by wind driven ice sheet.

Photograph 25 Cottage at Stevenson's Point near line 062 south of Winnipeg Beach on exposed point of land was damaged by ice pile-up. Ground elevation at cottage is 717. Small wood palisade behind beach has not been damaged in recent years.

Photograph 27 Ice piled up to a height of 15 feet on abandoned pier near line 128 west of Grand Marais. Note 2 diameter boulders in ice mound.

Photograph 26 Frame pumphouse on beach at Camp Morton near line 028 has not suffered ice damage since construction in 1938. Ground elevation at house is 718.

Photograph 28 Damage to Arnes Dock near 020 due to uplift associated with ice pile up. Note 15-foot pile of ice in dock.

Photograph 29 Ice pile-up near line 165 at Victoria Beach. Note limited length of maximum height mound suggests multiplier effect.

Photograph 30 Showing boulders pushed up the beach by wind driven ice sheet.

CHAPTER 8

OBSERVATIONS AND CONCLUSIONS

A. HISTORIC RATES OF SHORELINE RECESSION.

Historic longterm average shoreline recession rates were derived from analysis of available land survey plans and arial photographs as illustrated in Figure 10. The shoreline within the Study area was found to be generally eroding at rates of typically one to two feet per year with extreme values of zero to 25 feet per year. Historic recession rates around the perimeter of the Lake are summarized on Figures 11-1 to 11-5. Only at artificial littoral drift barriers such as docks and breakwaters was an advance of the shoreline, due to accretion of sand, observed. The erosion is attributable to the type of soil - clays, clayey to sandy tills, and outwash sands - forming the shoreline and to a long term rise in the level of the south pool resulting from continuing isostatic rebound of the northern outlet of the lake.

The land loss associated with the recorded erosion process amounts to some 15 acres per year. Excluding the marsh at the south end, the average annual loss of land along reaches of shoreline defined on Figure 16 is given in table 11.

Sediment generated by the erosion process amounts to some 510,000 tons per year, consisting 278,000 tons of silts and clays and 232,000 tons of sands, gravels and boulders. These values may be compared to some 2,650,000 tons per year of suspended sediment contributed by the Red River, consisting of approximately 2,570,000 tons of silts and clay and 80,000 tons of sand. The volume of silt and clay sediment generated by shoreline erosion process is roughly ten percent of the volume of silt and clay sediment contributed by the Red River.

B. EFFECT OF REGULATION ON SHORELINE RECESSION.

Regulating the level of the Lake by outlet control works is estimated to cause an initial increase in the rate of shoreline recession of approximately 50 percent. The rate is ten expected to decrease linearly with time and to approach the rates for equilibrium conditions as the shore profiles adjust to the new higher water levels. That is, along the east and west shorelines the rate of land loss will increase initially from the equilibrium rate of 15 acres per year to 23 acres per year for an average rate during the profile adjustment period of 19 acres per year.

The adjustment of the shore profile to the new higher water levels will result in a profile rise of typically 0.3 to 0.5 feet and a landward profile shift of typically 5 to 75 feet. The total area of land associated with this profile adjustment along the east and west shoreline is approximately 312 acres. Detailed data are given in Table 9 for the reaches defined on Figure 16.

The time required to effect the profile adjustments and the proportion of the profile shift which may be considered as a damage attributable to the regulation of the Lake level depends on the erosion-time model used in the analysis. The current state of the art of shoreline engineering is not adequate to ascertain the degree to which the two proposed models apply.

The model giving the lower limits (Case 1) suggests the profile shift would occur over a period of typically 5 to 40 years and that approximately 20 percent (62.5 acres) of the land loss associated with the profile shift would be attributable to the regulation of the Lake level. On this basis the weighted average time to effect the profile adjustments is approximately 16 years.

The model giving the upper limits (Case 2) suggests the profile shift would occur over a period of typically 20 to 200 years and implies that 100 percent (312 acres) of the land loss associated with the profile shift would be attributable to the regulation of the Lake level. On this basis the weighted average time to effect the profile adjustments is approximately 80 years. It should be noted that the total land loss during this time period would be approximately 1500 acres. A summary of the time for profile adjustments is given in Table 15.

The volume of sediment generated as a result of the total profile adjustment from recorded to regulated is estimated to be 8,800,000 tons, consisting of 6,000,000 tons of silt and clay and 2,200,000 tons of sands, gravels and boulders. This may be compared to an average annual sediment load in the Red River of 2,570,000 tons of silt and clay and 80,000 tons of sand.

C. MITIGATION OF DAMAGES AND ENHANCEMENT OF BENEFITS WITH RESPECT TO SHORELINE EROSION.

Where shoreline development planning or existing developments require the arresting of the erosion process consideration should be given to the use of artificial sand beaches confined by groin type structures to provide both erosion protection and recreational facilities. The narrowing of the range of lake levels and the reduction of peak levels would make the design of such structures less costly and more practical.

D. AVAILABILITY OF SAND AROUND SHORELINE.

The west shore is deficient in sand for beaches except at Gimli and Winnipeg Beach. The lack of sand reduces the recreational capability of the shoreline and also contributes to increased erosion of the predominantly clay shoreline.

Portions of the south shoreline have extensive volumes of sand below the water level. Beach ridges and dunes above the water level are generally not extensive and are backed by low lying marshy land. Development of these sand deposits for beaches is likely possible but would require extensive and costly dredging of sand.

Excellent sand beaches exist along the east shore at Patricia Beach, Grand Beach, Hillside Beach, Victoria Beach and Albert Beach and Elk Island. Patricia, Grand and Hillside Beaches are bay mouth bars with sand dunes back of the beach. The Victoria and Elk Island beaches are formed by the erosion of sandy bluffs. However, there are extensive reaches of shoreline with boulder and cobble beaches.

E. EFFECT OF REGULATION ON SAND BEACHES.

Along the west shore the increase in wave energy reaching the shoreline during the profile adjustment stage is expected to increase the rate at which sand is transported along the shore. Concurrently the generation of sand as an erosion product will increase

as well. It is believed that the two effects will compensate each other and that the net effect will be a minor change in the availability of sand - in some areas an increase and in others a decrease.

Along the south shore and at Patricia Beach the profile adjustment associated with regulation of the lake level is expected to cause the shoreline to recede approximately 50 feet over a period of time estimated to be in the range of 10 to 50 years.

At Grand Beach, Hillside Beach, Victoria Beach and Elk Island the profile adjustment associated with regulation of the lake level is estimated to cause the shoreline to recede some 5 to 10 feet over a period of 5 to 25 years.

F. MITIGATION OF DAMAGES AND ENHANCEMENT OF BENEFITS WITH RESPECT TO SAND BEACHES.

In the case of eroding sandy bluffs it is considered best to permit the erosion associated with the profile adjustment to take place. Attempts to stop the erosion are likely to impair the sand beach. The recession of the top of the bank will generally not be great enough to cause major damage to existing developments.

In the case of bay mouth bar beaches such as those at Patricia, Grand and Hillside beaches the profile adjustment will cause a loss of beach sand from the dunes which could only be replaced by dredging offshore sand. The feasibility and economics of such measures require further study.

As noted earlier, the narrowing of the range of lake levels during the open water season would simplify the design and reduce the cost of artificial beaches.

G. HISTORIC SHORELINE DAMAGE DUE TO ICE EFFECTS.

Analytical computations and a survey of lakeshore residents indicate that shoreline damage due to ice effects is uncommon and requires an unusual combination of circumstances. The lack of damage is partly attributable to the fact that people recognize wave and ice action to be severe and therefore do not construct light docks and boat houses which would be damaged.

H. EFFECT OF REGULATION OF THE LAKE ON SHORELINE DAMAGE BY ICE.

The conclusions derived from the field evidence concur with those derived from analytical computations and may be summarized as follows:

1. Ice shove due to the thermal expansion of the ice sheet does not cause significant damage.
2. During the spring ice break up period, ice pile up due to wind forces is common. However, the pile up normally occurs offshore or on the beach and does not damage buildings or trees.
3. High mounds of ice pile up are normally associated with wind acting on a wide ice sheet pushing against a narrower structure or shoreline.
4. Damage to shoreline buildings appears to have a frequency of once or less in a lifetime and depends on a rare combination of high onshore winds (say greater than 30 m.p.h.) from a narrow sector (say 45°) during a short interval of time (say 2 weeks) together with the multiplier effect on a long ice sheet acting on a short shoreline. Additionally, the water level must be sufficiently high so that the ice piles up near enough to the shoreline to damage shore structures.

5. The lower spring lake levels in comparison to the fall lake levels will result in reduced onshore ice piling and reduced damage to beaches and beach works.

It is anticipated that regulation of the level of the lake will cause a modest reduction in shoreline damage by ice. This would be a minor change in a phenomenon of minor importance.

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ANNEX 1

WIND SETUP

1.0 DEFINITION OF WIND SETUP

A wind blowing across the surface of a body of water tends to move the surface water in a downwind direction. This action causes a rise in water level at the downwind end of the lake - called a setup - and a corresponding drop in the water level at the upwind end of the lake - called a setdown.

2.0 FACTORS AFFECTING WIND SETUP

For the simple case of a rectangular lake of constant depth the wind setup is given by the formula: $S=\frac{V^2F}{1400D}$

where S = wind setup above still water level in feet

V = wind velocity in miles per hour

F = fetch distance or length of lake measured parallel to the wind direction in miles

D = mean depth of lake in feet

Substituting representative values for Lake Winnipeg:

V = 30 miles per hour

F = 250 miles from N to S

D = 40 feet

$S = \frac{30^2 \times 250}{1400 \times 40} = 4$ feet

The highest recorded setup on Lake Winnipeg was 3.78 feet at Gimli on October 3, 1970. The wind blew from the N to NW for a period of 24 hours at an average speed of 20 m.p.h. (range 12 to 28).

In the case of Lake Winnipeg as in most cases the width and depth of the lake vary over its length. Additionally the development of setup requires the transfer of large quantities of water from one end of the lake to the other - a process which requires considerable time particularly if the lake contains narrow constricted sections. For these reasons the computation of wind setup requires a more complex analysis which recognizes the variable dimensions of the lake and the time required for the water transfer.

3.0 DISTRIBUTION OF SETUP AROUND LAKE WINNIPEG

Examination of simultaneous water level recordings from several points around the perimeter of Lake Winnipeg indicates that maximum setups require a transfer of water from one end of the lake to the other and produce a corresponding tilting of the total lake surface. Figure 1 indicates the location of several water level recorders

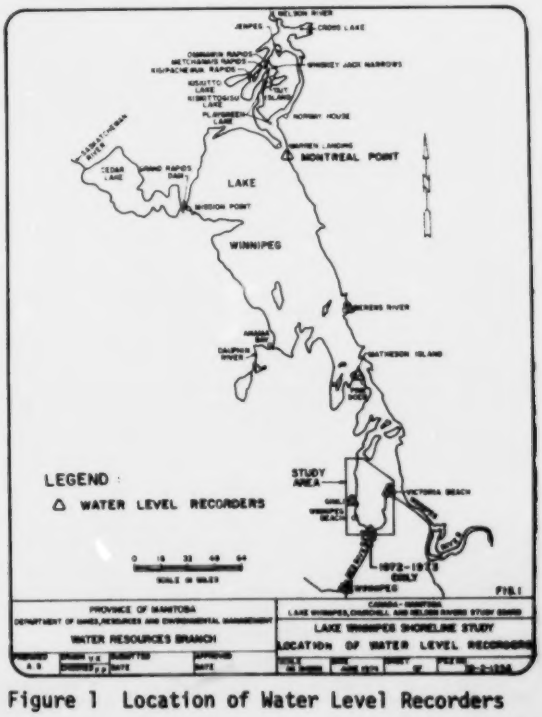


Figure 1 Location of Water Level Recorders

and Figures 2 and 3 indicate the simultaneous water surface elevations measured by these recorders during October and November, 1971. The data on Figure 2 show that on November, 1971. The data on Figure 2 show that on November 6 a rise in water level at the south end (Gimli) was associated with a fall at the north end (Montreal Point) while the water level near the midpoint of the lake (Berens River) maintained an intermediate level. On November 22, as shown on Figure 3, the opposite effect took place. Successive north-south water surface profiles for these periods are shown on Figures 4 and 5. It is seen that the profile at any point in time is complex and the result of the current and antecedant wind conditions.

The variation in wind setup over that part of the lake within the Study Area is not great. Examination of water level recorder charts from Gimli and Victoria Beach indicates that the levels at these two stations to be virtually identical, differences seldom exceed 0.1 feet for setups in the range of 1 to 2 feet. The levels at the mouth of the Red River follow those at Gimli although the magnitude of the setups and setdowns is greater. The wind setup observed at the mouth of the Red River was correlated with that observed at Gimli for three hour intervals of time for the open-water periods in 1972 and 1973. Only setups in excess of 0.5 feet at Gimli were included. The

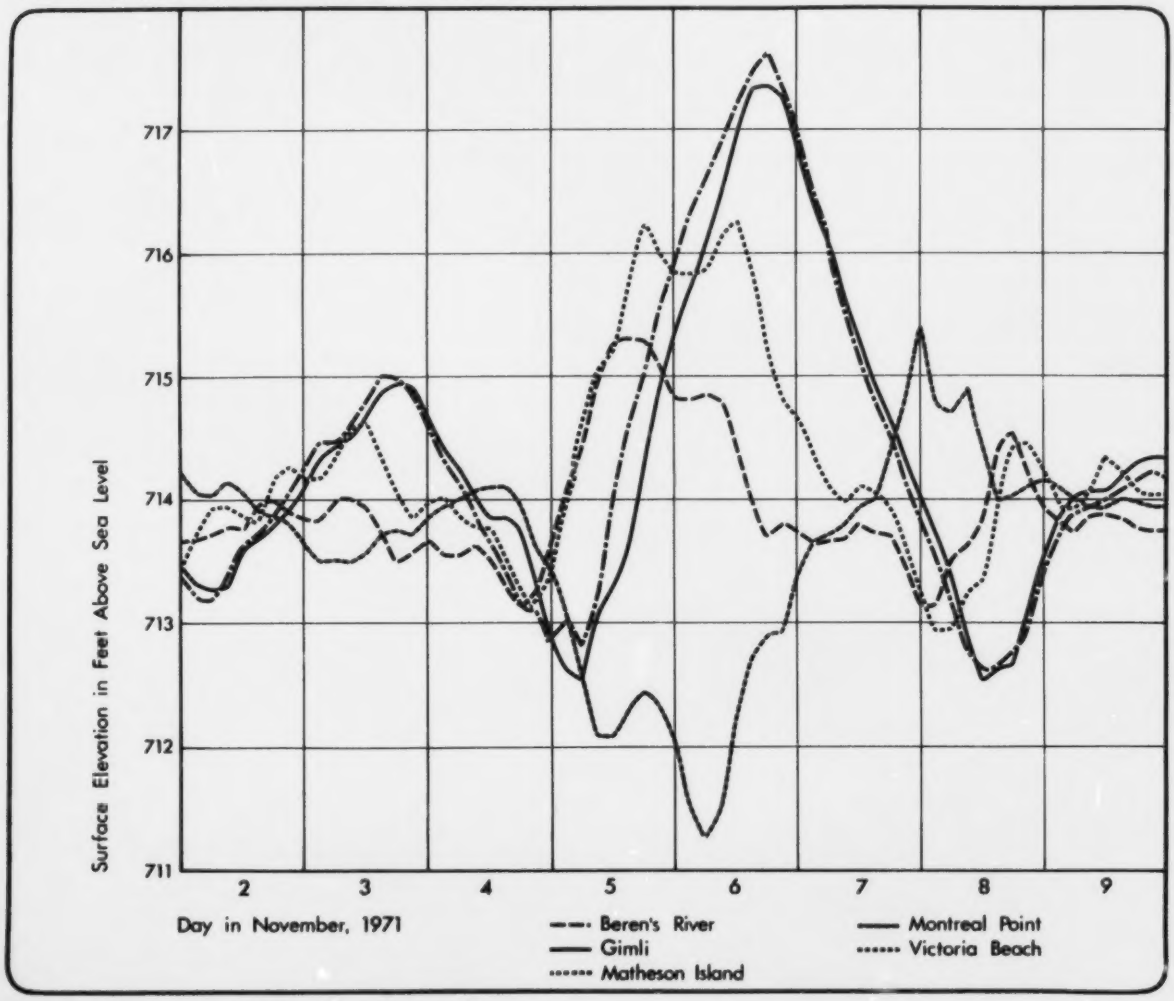


Figure 2 Water Level Elevation Versus Time

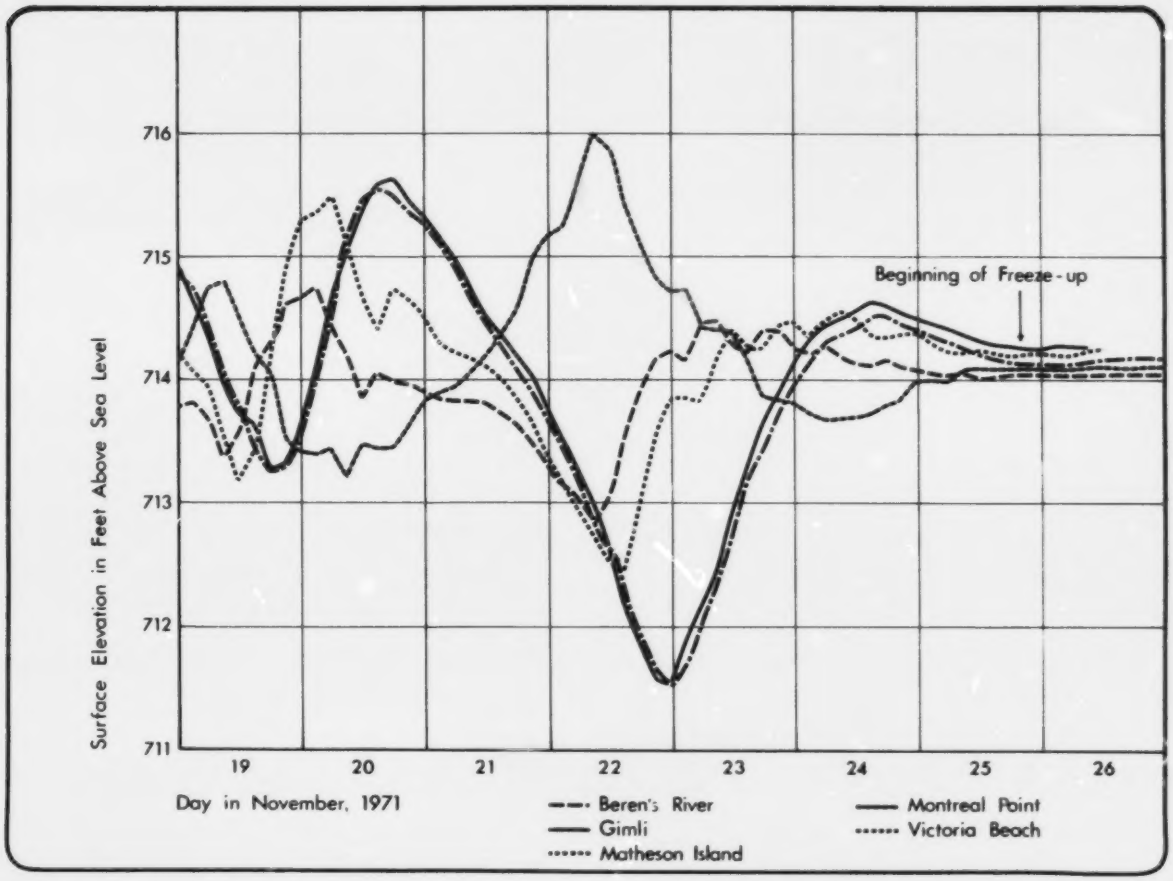


Figure 3 Water Level Elevation Versus Time

wind setup is 12 to 20 percent greater at the mouth of the Red River than the wind setup at Gimli. The resultant logarithmic and linear relationships from the analysis indicate the same increased magnitude (approximately 12%) of wind setup at the mouth of the Red River for wind setups between 0 and 1.5 feet at Gimli. However, for wind setups larger than 1.5 feet at Gimli, the logarithmic relationship indicates a greater degree (approximately 8%) of wind setup than the linear relationship at the mouth of the Red River. It is felt that for setups larger than 1.5 feet at Gimli, the logarithmic relationship represents the setups at the mouth of the Red River more accurately. The results of the logarithmic and linear analysis are shown on Figure 6.

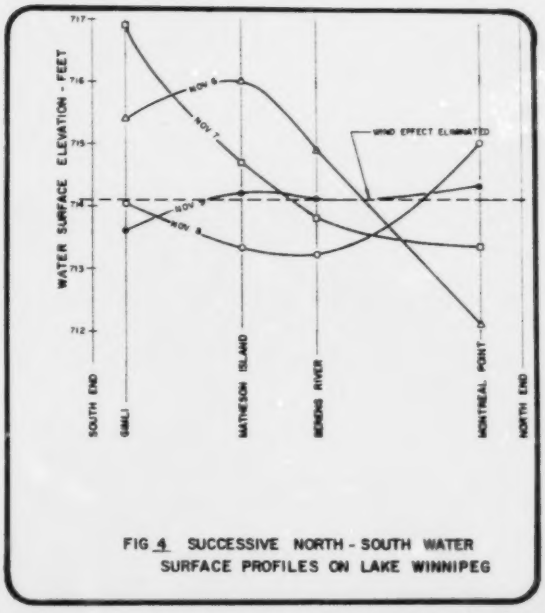


Figure 4 Successive North-South Water Surface Profiles on Lake Winnipeg.

4.0 TIME REQUIRED FOR DEVELOPMENT OF WIND SETUP

Examination of water level recorder charts indicates that the level of the lake at any one point on its surface varies from a minimum to a maximum (or vice versa) over a period of typically 24 hours. At Gimli the maximum rate of water level rise is about 1 foot per 6 hours, although a rise of 1 foot per 12 hours is more typical.

The increased setup at the mouth of the Red River is likely a local effect due in large part to the shallow depth of water near the shore. For most practical purposes the setup observed at Gimli may be considered to apply to the total area of lake within the Study Area.

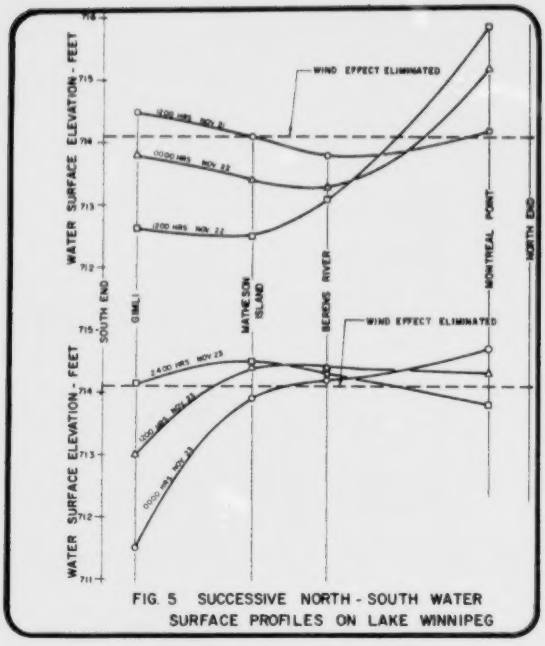


FIG. 5 SUCCESSIVE NORTH - SOUTH WATER SURFACE PROFILES ON LAKE WINNIPEG

Figure 5 Successive North-South Water Surface Profiles on Lake Winnipeg.

5.0 FREQUENCY OF WIND SETUP

The water level recordings at Gimli - Winnipeg Beach for the period 1933 to 1970 were analysed for wind setup and setdown. A wind effect eliminated lake level line was drawn on the recorder charts and the maximum deviation of the recorded level from this line was abstracted for each day as the setup or setdown for that day. A single setup event extending over two days would be recorded as two separate setups. Only setups greater than one foot and setdowns greater than one half foot were included. Separate analysis were made for the period May to August and September to November. The results of the analysis are shown on Figure 7 and Figure 8. The curves give the number of days out of 100 during which the maximum difference between the actual and the wind effect eliminated level was less than the amount stated. The data is presented in another form in the following Table 1.

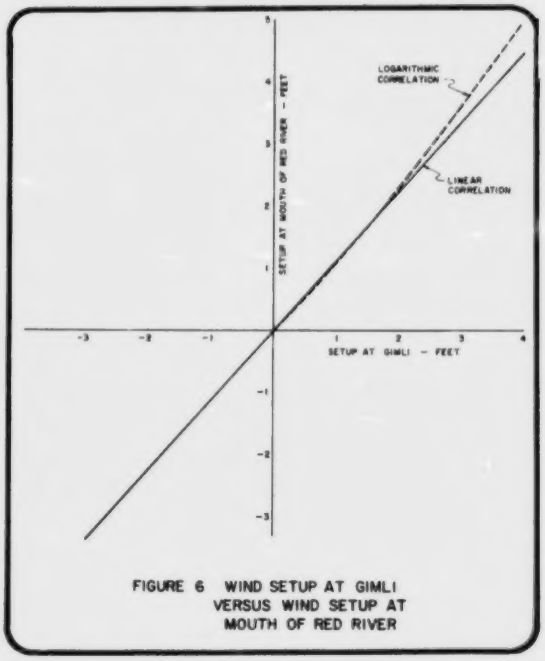


FIGURE 6 WIND SETUP AT GIMLI VERSUS WIND SETUP AT MOUTH OF RED RIVER

Figure 6 Wind Setup At Gimli Versus Wind Setup At Mouth of Red River.

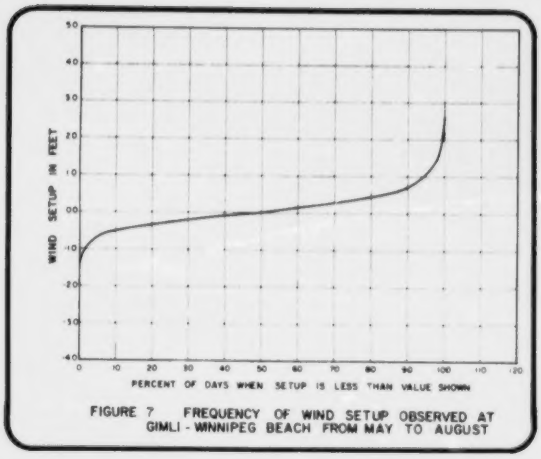


FIGURE 7 FREQUENCY OF WIND SETUP OBSERVED AT GIMLI - WINNIPEG BEACH FROM MAY TO AUGUST

Figure 7 Frequency of Wind Setup observed At Gimli - Winnipeg Beach From May to August

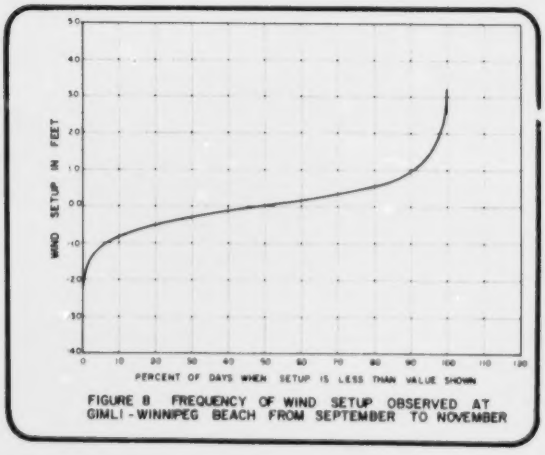


FIGURE 8 FREQUENCY OF WIND SETUP OBSERVED AT GIMLI - WINNIPEG BEACH FROM SEPTEMBER TO NOVEMBER

Figure 8 Frequency of Wind Setup Observed at Gimli - Winnipeg Beach From September to November.

TABLE I

FREQUENCY OF WIND SETUP AT GIMLI-WINNIPEG BEACH

No. of Days in Which Wind Setup Exceeds Height Shown

PERIOD	-1.5'	-1.0'	-0.5'	0	+1.0'	+1.5'	+2.0'	+2.5'
May 15 - Aug. 31		2.1	10.5		5.7	1.9	.6	.2
Sept. 1 - Nov. 15	1.5	5.2	15.0		6.8	3.2	1.5	.6
May 15 - Nov. 15	1.5	7.3	25.5		12.5	5.1	2.1	.8

ANNEX 2

WAVE MEASUREMENT AND ANALYSIS

1.0 INTRODUCTION

The action of wind generated water waves is one of the most important factors in shoreline erosion and in the movement of sand along the shoreline.

While it is possible to estimate the characteristics of such waves from other physical data, such estimates, especially in the case of shallow water lakes, such as Lake Winnipeg, yield approximate and sometimes conflicting data depending on the method of analysis employed. For this reason a program of field measurement of wave characteristics was carried out.

2.0 THEORY OF WATER WAVES

The basic theory of water waves given below is reproduced largely from "Shore Protection, Planning and Design", U.S. Army Coastal Engineering Research Centre, Technical Report No. 4, 1966.

The following elements are covered:

1. Basic equations for sinusoidal waves TR#4 pp. 1, 2, 3
2. Forecasting techniques for deep water areas. TR#4 pp. 17, 19, 6
3. Waves in transitional and shallow water TR#4 pp. 62, 63
4. Refraction of waves TR#4 pp. 63
5. Breaking waves TR#4 pp. 101, 102, 104

2.1 BASIC EQUATIONS FOR SINUSOIDAL WAVES

Waves generated in deep water are usually of the type known as oscillatory waves, in which the particles of water making up the wave oscillate in a circular orbit about some mean position (See Figure 1).

An oscillatory wave, provided it is sinusoidal, is well defined if the wave length, L, the horizontal distance between corresponding points on two successive waves; the wave height, H, the vertical distance to a crest from the preceding trough; the wave period, T, the time for two successive crests to pass a given point; and the depth, d, over which the wave moves, are known. The velocity, C, with which an oscillatory wave progresses, is related to period and length by

$$L = CT \qquad (1\text{-}1)$$

and to the depth and length by

$$C^2 = \frac{gL}{2\pi} \tanh \frac{2\pi d}{L} \qquad (1\text{-}2)$$

where g is the acceleration of gravity. As the water depth becomes large relative to the wave length, the hyperbolic tangent function ($\tanh \frac{2\pi d}{L}$) approaches unity, the wave velocity becomes independent of depth, and

$$C^2 = \frac{gL}{2\pi} \qquad (1\text{-}3)$$

This condition (i.e., where the depth is great enough so that wave characteristics are independent of depth) is termed "deep water"; deep water conditions are generally indicated by the subscript "o" as L_o and C_o.

For deep water conditions, since $L_o = C_o T$, then,

$$C_o = \frac{gT}{2\pi} = 5.12\ T \qquad (1\text{-}4)$$

(where T is in seconds and C_o is in feet per second)

And

$$L_o = 5.12\ T^2 \qquad (1\text{-}5)$$

(where the deep water wave length L_o is in feet, and T is in seconds)

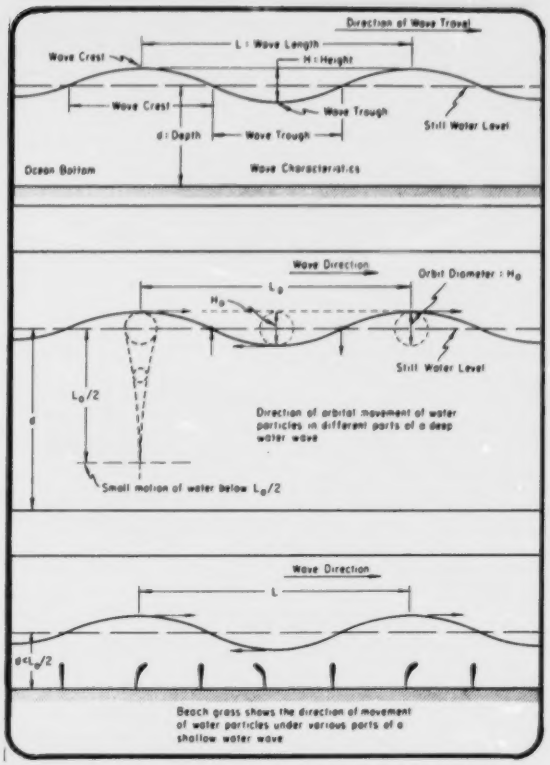


Figure 1 Wave Characteristics And Directions of Water Particle Movement.

Although "deep water" actually occurs only at an infinite depth, the tanh $2\pi d/L$ approaches unity closely at much smaller ratios of depth to wave length - called relative depth, d/L. For a relative depth of 0.5 (that is, when the depth is one half the wave length) the tanh $2\pi d/L$ is 0.9963, and this relative depth has, by general usage, been arbitrarily accepted as deep water. (However, for certain work requiring less precision, the deep water limit may be taken at some other relative depth. For example, the error in velocity computations is only 8 percent if a relative depth of 0.25 is considered deep water).

When the water depth becomes quite shallow, the hyperbolic function tanh $2\pi d/L$ approaches $2\pi d/L$ and the wave velocity becomes:

$$C^2 = gd \qquad (1\text{-}6)$$

Water of such a depth that equation 1-6 applies is termed "shallow water". The

limiting depth for "shallow water" has, by general usage, been accepted as 1/25 the wave length. Water having a depth between 1/2 and 1/25 the wave length is termed "transitional".

The total energy per unit crest width in one wave length of an oscillatory wave (i.e., the total energy in a single wave of unit width) is given by

$$E_t = \frac{\rho g H^2}{8} \left(1 - M \frac{H^2}{L^2}\right) \qquad (1\text{-}7)$$

in f.p.s. units where P = w/g is the mass density of water (salt water = 2.0 lbs sec^2/ft^4 or 2.0 slugs/ft^3; fresh water = 1.94 lbs sec^2/ft^4 or 1.94 slugs/ft^3) and M is an energy coefficient defined as

$$M = \frac{\pi^2}{2 \tanh^2 (2\pi d/L)} \qquad (1\text{-}8)$$

The energy in the f.p.s. system would, of course, be in foot-pounds per foot width of wave crest.

It is of some interest to note that for deep water waves (d>L/2), the value of M approaches 4.935, and the value of E_t can be approximated by the simple relation:

$$E_t = \frac{WLH^2}{8} \qquad (1\text{-}9)$$

or, for seawater weighing 64 lbs per cubic foot:

$$E_t = 8LH^2 \qquad (1\text{-}10)$$

in ft lbs per unit width per wave. For more exact computation, the full equation should, of course, be used. The values of M associated with various values of d/L are given in Table D-1 of Appendix D of "Shore Protection, Planning and Design", U.S. Army Coastal Engineering Research Centre, Technical Report Number 4, 1966.

It should be recognized that the total energy, E_t, of a wave train is composed of two parts, the kinetic energy, E_k, and the potential energy, E_p. The kinetic energy (E_k) is that part of the energy represented by the water particle velocity associated with the wave motion. The potential energy (E_p) is that part of the energy represented by the fact that part of the fluid mass has been lifted out of the wave trough and appears above the mean water level as the wave crest. The relation, of course, holds that

$$E_t = E_k + E_p \qquad (1\text{-}11)$$

Another relationship associated with the mechanics of wave action is the fact that

$$E_k = E_p \qquad (1\text{-}12)$$

The value of the energy, E_f, moving forward with the wave train can be computed from the relationship:

$$E_f = nE_t \qquad (1\text{-}13)$$

where

$$n = 1/2 \left[1 + \frac{4\pi d/L}{\sinh (4\pi d/L)}\right] \qquad (1\text{-}14)$$

In water deeper than one half the wave length, sinh (4πd/L) becomes very large and n therefore becomes very close to one half. Thus, at any selected point in deep water in a wave train, one half the total energy, E_t, in each wave of the wave train is moving forward, first, to create and, then to sustain the wave train out in front of the selected point. In most cases where a wave train approaches the shore from deep water, the energy that will be expended on the shore by a given wave is readily computed, as it is approximately one half the total energy of the deep wave. To compute the total energy expended on the shore in a given

time requires only multiplying the forward-moving energy, E_f of the single wave by the number of waves reaching the shore in the selected period of time. The total wave energy, E_t, reaching the shore per unit width of wave crest for a selected simple wave train in interval, t, would be:

$$E_t = E_f \frac{t}{T} \qquad (1\text{-}15)$$

This equation may be simplified as follows:

$$E_t = E_f \frac{t}{T} = nE_t \frac{t}{T} = 1/2 \frac{wLH^2}{8} \frac{t}{T}$$

$$= 1/2 \frac{w\ 5.12T^2H^2}{8} \frac{t}{T} = 1/2 \times \frac{62.4 \times 5.12\ TH^2t}{8}$$

$$= 20\ H^2Tt$$

2.2 FORECASTING TECHNIQUES FOR DEEPWATER AREAS (BRETSCHNEIDER REVISED, SVERDRUP-MUNK OR S-M-B METHOD)

Figure 2 is a plot of the forecasting curves presently in use by most coastal engineers in the United States . With these, one may determine the significant wave height, H_F, and significant wave period, T_F, at the front of a fetch, knowing the wind speed in the fetch, and either the duration of the wind or the fetch length. In using the plots, the actual wind velocity, U, the fetch length, F, and the estimated duration, t, of the wind, when a fetch first appears on a chart are tabulated. (When a fetch first appears on a chart the duration of the wind at the time of the chart may be taken as one half the time, Z, between charts).

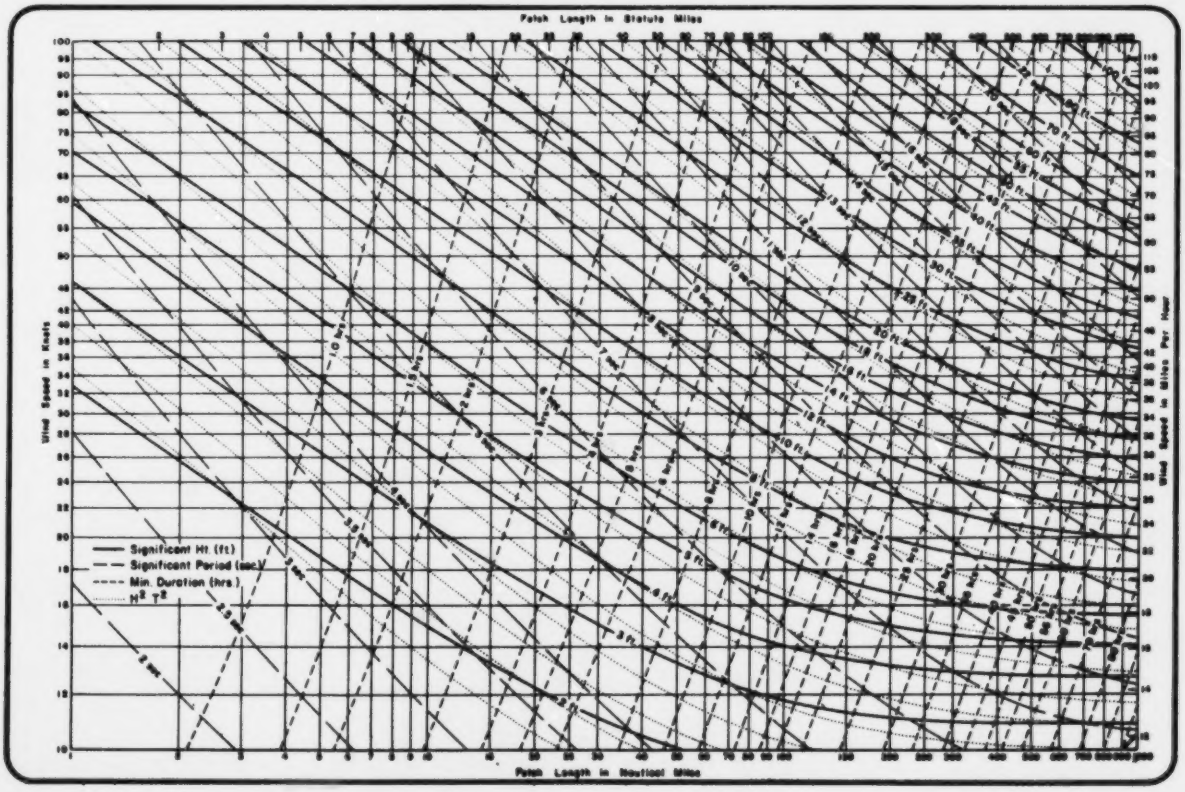


Figure 2 Deep water Wave Forecasting Curves As A Function of Wind Speed, Fetch Length, And Wind Duration. (For Fetchs 1 to 1000 miles).

Figure 2 is then entered with the known value of U, on the left if U is in knots, or on the right if in statute miles per hour. This U line is then followed from the left side of the graph across to its intersection with the fetch length F line, or the duration t line, whichever comes first. For example, with a wind of 35 knots or 40 mph, a duration of 10 hours comes before a fetch length of 200 nautical miles. Similarly an F of 80 nautical miles comes before a 't' of 10 hours. At this point H_F and T_F, the wave height and period at the head of the fetch, may be read off and tabulated. For the case given above with U = 35 knots, t = 10 hours, and F = 200, H_F = 14.7 feet, T_F = 9.6 seconds, t_m equals 10 hours, and F_m = 115 nautical miles. If F had been 80 nautical miles with t still 10 hours, the heights, periods, minimum duration and fetch would be H_F = 12.7 feet, T_F = 8.7 seconds, t_m = 7.6 hours and F_m = 80 nautical miles. The wave pattern in the first case where the duration is limiting, would correspond to the dashed line in Figure 3, that of the second case, where the fetch is limiting. to the solid line in Figure 3.

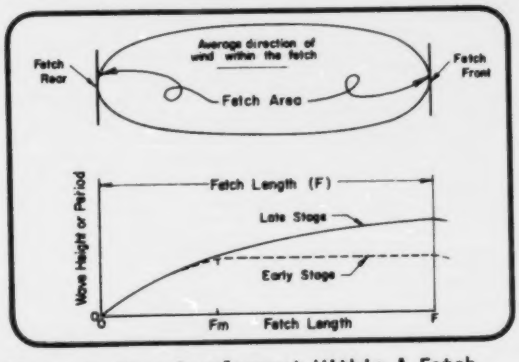


Figure 3 Wave Development Within A Fetch

2.3 WAVES IN TRANSITIONAL AND SHALLOW WATER.

From equation 1-2, it may be seen that wave velocity varies with the depth of water in which the wave is moving; as the depth decreases, the velocity also decreases. In addition, assuming constant wave period, equation 1-2 indicates that wave length also varies with water depth. The variation in wave velocity along the crest of a wave moving at an angle to underwater contours (i.e., that portion of the wave in deeper water is moving faster than the portion in shallow water), causes the crest to bend toward alignment with the contours. This effect, called refraction, is more or less significant depending on the relation of the water depth to the wave length.

In water deeper than one half the wave length, the hyperbolic tangent function in the formula

$$C^2 = \frac{gL}{2\pi} \tanh \frac{2\pi d}{L}$$

is nearly equal to unity, and equation 1-2 reduces to

$$C^2 = \frac{gL}{2\pi}$$

In this equation, the velocity, C, is not dependent on depth; therefore in those regions deeper than one half the wave length (deep water), refraction is not significant. In the region where water depth is between 1/2 and 1/25 the wave length (transitional water), and in the region where water depth is less than 1/25 the wave length (shallow water) refraction effects are significant. In the first of these, wave velocity must be computed from equation 1-2; in the second, tanh 2πd/L and equation 1-2 reduces to equation 1-6

$$C^2 = gd \text{ or } C = \sqrt{gd}$$

Both equations 1-2 and 1-6 show a dependence of wave velocity on depth. To a first approximation, equation 1-7 for total energy in a wave per unit crest width may be written as equation 1-9

$$E_t = \frac{w H^2 L}{8}$$

It has already been noted (equation 1-13) that the entire wave energy, E_t, is not transmitted forward with the wave, only 1/2 being transmitted forward in deep water as E_f. The value of this E_f for a given wave remains essentially constant as it moves from deep water to the breaker line.

The transformation of a wave in passing from deep water to shallow water to the breaking point is illustrated on Figure 4. The data is for a wave having a deep water wave height of 3 feet and a wave period of 4 seconds, which is typical for Lake Winnipeg. The wave period remains essentially constant as the wave moves to the breaking point.

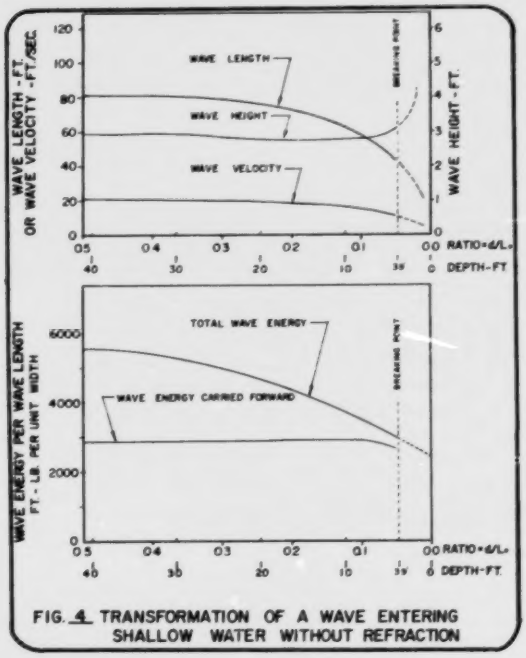


FIG. 4 TRANSFORMATION OF A WAVE ENTERING SHALLOW WATER WITHOUT REFRACTION

2.4 REFRACTION OF WAVES

Refraction of water waves is the process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours. See Figure 5. In performing refraction

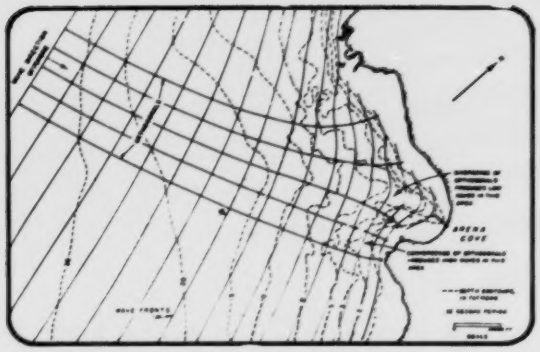


Figure 5 Wave Refraction Diagram.

analyses, it is assumed that for a wave advancing toward shore, no energy flows laterally along a wave crest. That is, the transmitted energy remains constant between two lines (called orthogonals) drawn perpendicular to a wave crest as it passes over changing hydrography. Details of the refraction diagram construction are included in TR #4 pages 63 to 72.

2.5 BREAKING WAVES

At a certain point in its advance toward shore, a wave becomes unstable, peaks up and breaks. The water motion changes from a laminar orbital motion to turbulent, white-water conditions. The determination of the point of breaking and height of breaking waves is of major importance in the planning and designing of shore protection measures.

Three different sets of curves, one theoretical and two empirical, are currently used to determine breaking depths and wave heights on breaking. The theoretical curve is derived from the analysis of a solitary wave and results in the following equations:

$$\frac{H_b}{H'_o} = \frac{1}{3.3\sqrt[3]{H'_o/L_o}} \qquad (1\text{-}34)$$

$$d_b/H_b = 1.28 \qquad (1\text{-}35)$$

$$d_b/H_o' = 1.28/3.3\sqrt[3]{H_o'/L_o} \qquad (1\text{-}36)$$

$$H_o' = \frac{1.837}{T}(d_b)^{2/3} \qquad (1\text{-}37)$$

$$d_b = 0.667\ (H_o'T)^{2/3} = 0.667\ H_o' \Big/ \left(\frac{H_o'}{T^2}\right)^{1/3} \qquad (1\text{-}38)$$

Graphs drawn from these relations as well as those from the two other studies are presented in Figures 6 and 7. All three curve sets relate the breaker depths, d_b, and the breaker height, H_b, to deep water wave length L_o and deep water wave height H_o and the refraction coefficient, K_R, H_o' may be determined from:

$$H_o' = K_R\ H_o = H_o\ (H/H_o') \qquad (1\text{-}39)$$

where

$$H = K_R\ (H/H_o')\ H_o = (H/H_o)\ H_o' \qquad (1\text{-}40)$$

and (H/H_o') or K_s is the shoaling coefficient. The solid line curves include the additional parameter of bottom slope, the effect of which was adequately verified under controlled laboratory conditions.

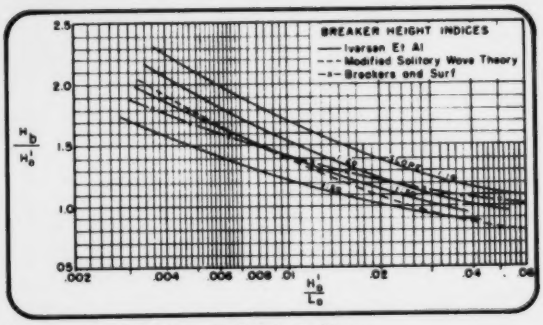


Figure 6 Breaker Height Indices

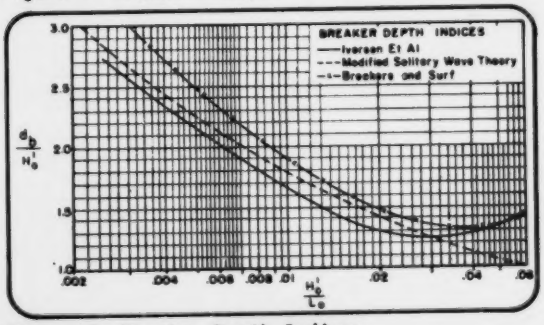


Figure 7 Breaker Depth Indices

To use the curves on Figures 6 and 7, H_o' is determined as above, L_o from the known relationship $L_o = 5.12T^2$, and the nearshore bottom slope from hydrographic charts. By computing the ration H_o'/L_o the ratios H_b/H_o' and d_b/H_o' may be obtained from the graphs and from these, H_b and d_b determined by multiplication by H_o'.

2.6 WAVE SPECTRA

The pure case of successive waves of identical characteristics rarely, if ever, is found in nature. Normally the wave system consists of waves of varying wave heights distributed about some mean. Several defined waves commonly referred to in literature are as follows:

H_{max} (= 1.77 H_s) maximum probable wave

H_{10} (= 1.27 H_s) Average of highest 10% of waves

H_{sig} (= 1.0 H_s) Significant wave, average of highest 33% of waves

H_{equi} (= 0.71 H_s) equivalent wave, a single wave having energy equal to the sum of energies of all real waves

H_m (= 0.625 H_s) mean wave height

Furthermore, waves of any given height are found to have varying periods. Table 1 shows how the heights and periods of 1000 consecutive waves are likely to be distributed.

If one superimposes waves of varying heights and periods travelling at varying velocities and possibly in varying directions one obtains the confused state of the water surface that is visible to the observer.

TABLE 1 Joint Distribution of H and T For Zero Correlation

Number of Waves per 1,000 Consecutive Waves for Various Ranges in Height and Period

Range in Relative Height	Range in Relative Period T/$\bar{T}$											
H/$\bar{H}$	0-.2	.2-.4	.4-.6	.6-.8	.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2.0	0-2.0	Accumulative
0- .2	.03	.50	2.05	4.86	7.68	8.09	5.31	1.92	.34	.03	30.81	30.81
.2- .4	.10	1.41	5.81	13.78	21.76	23.92	15.05	5.44	.08	.07	88.32	119.13
.4- .6	.14	2.06	8.54	20.23	31.95	33.65	22.10	7.99	1.44	.11	128.21	247.34
.6- .8	.16	2.40	9.91	23.48	37.08	39.06	25.65	9.27	1.67	.12	148.80	396.14
.8-1.0	.16	2.40	9.92	23.51	37.13	39.11	25.69	9.28	1.67	.12	148.99	545.13
1.0-1.2	.15	2.14	8.87	21.02	33.19	34.97	22.96	8.30	1.49	.11	133.20	678.33
1.2-1.4	.12	1.74	7.21	17.07	26.96	28.40	18.65	6.74	1.21	.09	108.19	786.52
1.4-1.6	.09	1.30	5.37	12.72	20.09	21.16	13.90	5.02	.90	.07	80.62	867.14
1.6-1.8	.06	.90	3.72	8.82	13.93	14.67	9.64	3.48	.63	.05	55.90	923.04
1.8-2.0	.03	.48	1.99	4.72	7.45	7.85	5.15	1.86	.33	.03	29.89	952.93
2.0-2.2	.03	.42	1.72	4.09	6.45	6.80	4.47	1.61	.29	.02	25.90	978.83
2.2-2.4	.01	.18	.76	1.80	2.84	2.99	1.97	.71	.13	.01	11.40	990.23
2.4-2.6	.01	.09	.39	.93	1.47	1.55	1.02	.37	.07		5.90	996.13
2.6-2.8		.04	.18	.43	.67	.71	.47	.17	.03		2.70	998.83
2.8-3.0												
0.3.0	1.09	16.06	66.44	157.46	248.65	262.93	172.03	62.16	11.18	.83		
Accumulative	1.09	17.15	83.59	241.05	489.70	752.63	924.66	986.82	998.00	998.83		

It is possible by means of suitable instrumentation to obtain a record of the elevation of the water surface at a fixed location as a function of time. If one assumes that the complex composite record thus obtained consists of a series of superimposed simple sinusoidal waves of varying heights and periods but all travelling in the same direction, one can by certain mathematical techniques separate the composite record into its component parts. The results of the analysis are presented in some form of what is termed a "wave spectrum".

The "wave spectrum" is illustrated by the following example from Lake Winnipeg. The Wave Rider data is compiled by the Wave Climate Group in the form of Table 2. The given data can be manipulated as illustrated in Table 3 and then presented as on Figure 8. The value of the spectral density curve lies in its clear presentation of how the energy is distributed among the various frequency (or period) ranges. A single peak in the curve as in the example indicates a single wave system, whereas two peaks in the curve would suggest the presence of two systems.

The precision of the curve can be increased by using smaller increments of frequency as illustrated by the computer generated curve on Figure 9.

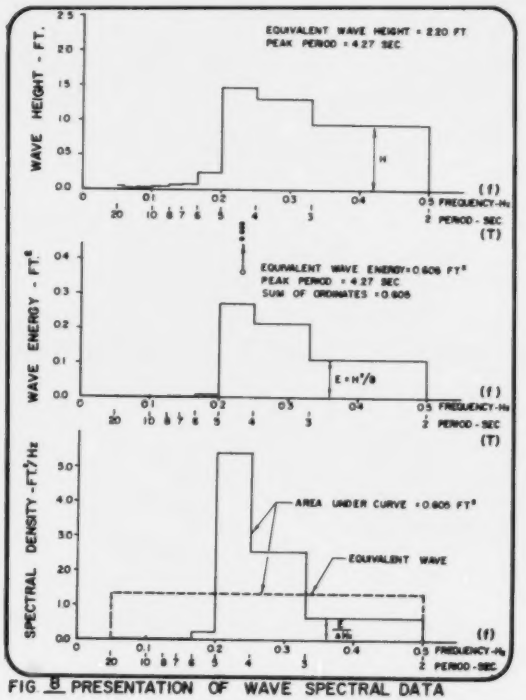


FIG 8 PRESENTATION OF WAVE SPECTRAL DATA

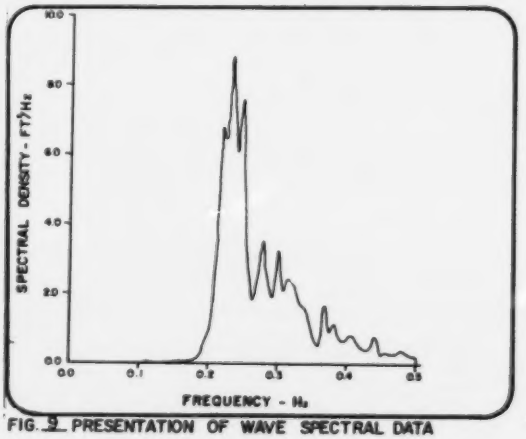


FIG. 9 PRESENTATION OF WAVE SPECTRAL DATA

STATION 71 WAVES RECORDED OFF GIMLI, LAKE WINNIPEG. PAGE 1

EQUIVALENT WAVE HEIGHT TABULATED BY WAVE PERIOD

RECORD -SIDE -TAPE	SEP HOUR-DAY	1971	2.0 TO 3.0 SEC	3.0 TO 4.0 SEC	4.0 TO 5.0 SEC	5.0 TO 6.0 SEC	6.0 TO 7.0 SEC	7.0 TO 8.0 SEC	8.0 TO 9.0 SEC	9.0 TO 10.0 SEC	10.0 TO 11.0 SEC	11.0 TO 12.0 SEC	12.0 TO 13.0 SEC	13.0 TO 14.0 SEC	14.0 TO 15.0 SEC	15.0 TO 16.0 SEC	16.0 TO 20.0 SEC	2.0 TO 20.0 SEC	WAVE ERGY FEET SQR.	PEAK PER. SEC.
2-1-1	1200	15	0.60	0.29	0.06	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.67	0.06	2.90
3-1-1	1500	15	0.49	0.28	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.56	0.04	2.97
4-1-1	1800	15	0.15	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.16	0.00	2.40
5-1-1	2100	15	0.40	0.16	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.43	0.02	2.84
6-1-1	0	16	0.32	0.15	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.36	0.02	2.97
7-1-1	300	16	0.25	0.07	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.27	0.01	2.28
8-1-1	600	16	0.15	0.05	0.02	0.01	0.01	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.16	0.00	2.07
9-1-1	900	16	0.45	0.07	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.46	0.03	2.28
10-1-1	1200	16	0.67	0.73	0.11	0.03	0.03	0.03	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.03	1.00	0.12	3.50
11-1-1	1500	16	0.82	1.26	0.38	0.09	0.05	0.04	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.04	1.55	0.30	3.69
12-1-1	1800	16	0.92	1.32	0.86	0.14	0.06	0.05	0.05	0.05	0.03	0.02	0.03	0.03	0.02	0.02	0.04	1.83	0.42	3.90
13-1-1	2100	16	0.90	1.09	0.51	0.10	0.05	0.04	0.04	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.03	1.51	0.29	3.90
14-1-1	0	17	0.79	1.36	0.85	0.10	0.05	0.04	0.03	0.05	0.04	0.02	0.02	0.03	0.02	0.02	0.04	1.79	0.40	3.79
15-1-1	300	17	0.79	0.99	0.90	0.13	0.07	0.04	0.04	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.04	1.56	0.31	4.14
16-1-1	600	17	0.75	0.83	0.18	0.04	0.03	0.03	0.03	0.04	0.06	0.03	0.02	0.01	0.01	0.02	0.03	1.14	0.16	3.41
1-2-1	900	17	0.73	0.96	0.36	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	1.26	0.20	3.69
2-2-1	1200	17	0.69	0.74	0.31	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	1.06	0.14	3.69
3-2-1	1500	17	0.71	0.65	0.10	0.07	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.97	0.12	3.41
4-2-1	1800	17	0.70	0.48	0.08	0.06	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.86	0.09	2.97
5-2-1	2100	17	0.42	0.26	0.03	0.02	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50	0.03	2.97
6-2-1	0	18	0.24	0.04	0.02	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.25	0.01	2.58
7-2-1	300	18	0.08	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.09	0.00	2.10
8-2-1	600	18	0.20	0.03	0.02	0.01	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.21	0.01	2.17
9-2-1	900	18	0.39	0.07	0.03	0.02	0.02	0.02	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.40	0.02	2.01
10-2-1	1200	18	0.82	0.17	0.05	0.03	0.03	0.04	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.84	0.09	2.24
11-2-1	1500	18	0.91	0.31	0.06	0.02	0.02	0.02	0.07	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.87	0.10	2.68
12-2-1	1800	18	0.84	0.59	0.11	0.03	0.03	0.03	0.06	0.06	0.02	0.02	0.01	0.02	0.01	0.01	0.02	1.04	0.13	3.03
13-2-1	2100	18	0.83	0.52	0.07	0.03	0.02	0.02	0.05	0.06	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.99	0.12	3.10
14-2-1	0	19	0.79	0.94	0.20	0.06	0.04	0.03	0.04	0.06	0.04	0.02	0.02	0.02	0.02	0.02	0.03	1.26	0.20	3.41
15-2-1	300	19	0.80	0.99	0.20	0.05	0.03	0.02	0.02	0.05	0.03	0.02	0.02	0.02	0.01	0.01	0.04	1.29	0.21	3.59
16-2-1	600	19	0.85	1.06	0.36	0.08	0.04	0.03	0.03	0.05	0.05	0.03	0.02	0.02	0.03	0.03	0.04	1.41	0.25	3.50
1-1-2	900	19	0.67	0.83	0.24	0.06	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.03	1.10	0.15	3.59
2-1-2	1200	19	0.49	0.42	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.03	0.64	0.05	2.90
3-1-2	1500	19	0.22	0.05	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.23	0.01	2.20
4-1-2	1800	19	0.06	0.04	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.10	0.00	2.01
5-1-2	2100	19	0.78	0.38	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.87	0.09	2.90
6-1-2	0	20	0.82	1.07	0.23	0.06	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.04	1.37	0.24	3.41
7-1-2	300	20	0.63	0.61	0.14	0.04	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.89	0.10	3.03
8-1-2	600	20	0.73	0.59	0.11	0.04	0.03	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.95	0.11	3.25
9-1-2	900	20	0.83	1.23	0.89	0.17	0.06	0.06	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.04	1.75	0.38	3.90
10-1-2	1200	20	0.65	0.80	0.33	0.07	0.03	0.04	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	1.09	0.15	3.41
11-1-2	1500	20	0.49	0.28	0.03	0.02	0.01	0.02	0.06	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.56	0.04	2.73
12-1-2	1800	20	0.76	0.52	0.05	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.93	0.11	2.90
13-1-2	2100	20	0.75	0.65	0.22	0.04	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.88	0.10	3.50
14-1-2	0	21	0.49	0.22	0.05	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.54	0.04	2.68
15-1-2	300	21	0.46	0.27	0.05	0.02	0.03	0.01	0.01	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.54	0.04	2.79
16-1-2	600	21	0.42	0.11	0.04	0.02	0.01	0.01	0.02	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.45	0.03	2.24
1-2-2	900	21	0.48	0.29	0.05	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.57	0.04	3.03
2-2-2	1200	21	0.80	0.92	0.16	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	1.23	0.19	3.50

Table 2 Compiled Wave Rider Data

To simplify computations for the purpose of this report, the wave spectrum as measured by the Wave Rider instruments will be replaced by a single equivalent wave having an energy equal to that of the wave system and a period equal to the period at which the maximum energy occurs. This will be known as the equivalent wave at the peak period.

3.0 WAVE MEASUREMENT PROGRAM

The wave measuring equipment was supplied and installed by the Wave Climate Study, Marine Engineering Division, Department of Public Works of Canada. The Wave Climate Study also processed the wave data and presented it in summary form.

3.1 INSTRUMENTATION

Datawell "Waverider" accelerometer buoys transmitting to shorebased recorders were used. The buoys were moored in about 30

TABLE 3

WAVE SPECTRUM COMPUTATIONS

WAVE PERIOD T (sec)	WAVE FREQUENCY $\frac{1}{T} = f(H_z)$	FREQUENCY INCREMENT $\Delta f(H_z)$	WAVE HEIGHT H(ft.)	WAVE ENERGY $E = \frac{H^2}{8}(ft.^2)$	SPECTRAL DENSITY $\frac{E}{\Delta f}(ft.^2/H_z)$
2-3	.500-.33	.167	.94	.111	.660
3-4	.333-.250	.083	1.51	.214	2.58
4-5	.250-.200	.050	1.47	.270	5.40
5-6	.200-.167	.033	.24	.0072	.22
6-7	.167-.143	.024	.08	.0008	.03
7-8	.143-.125	.018	.07	.0006	.03
8-9	.125-.111	.014	.05	.0005	.02
9-10	.111-.100	.011	.05	.0003	.03
10-11	.100-.091	.009	.04	.0002	.02
11-12	.091-.083	.008	.04	.0002	.02
12-13	.083-.077	.006	.04	.0002	.02
13-14	.077-.072	.005	.02	.00005	.01
14-15	.072-.067	.005	.03	.0001	.02
15-16	.067-.063	.004	.03	.0001	.02
16-17	.063-.059	.015	.05	.0005	.02
2-20*	.500-.050	.450	2.20	.606	1.35

*NOTE: - Equivalent wave height is 2.20 feet and peak period is 4.27 seconds.

- Wave energy is expressed as ft.-lbs. per sq. ft. of water surface per unit weight of water.

- Record is for 0600 hrs., 2 Oct. 1971 at Gimli.

feet of water and were located 1.5 miles east of Gimli and 1.0 miles north of Grand Beach.

3.2 DATA PRESENTATION

The data is presented in summary form as shown on Table 2.

3.3 USE OF DATA

To simplify computations for the purposes of this report, the wave climate during any recording interval will be represented by a single wave having a height equal to the equivalent wave height for the total range of periods and a wave period corresponding to that at which the peak energy occurs.

3.4 SUMMARY OF PROCEDURE AND COMPUTER PROGRAMS

The following section provides additional detail on computational procedures.

Programs

The computer programs used in the study are listed below. A description of each program is given in the text following:

1) Load and Fill Gaps in Data Base

i) A26 Load and A26 Fill - Load the Data Base

ii) A26 Waves - Regression Program

iii) A26GPFIL - Apply Regression Results to Data Base

iv) A262OH2T - Put Energy = $2OH^2T$ in Data Base

v) A26FIX - Apply Correction Cards to Data Base

vi) A26LIST - List the Data Base

2) Analysis of Data Base and Output of Results

vii) A26HIGHT - Plot Wave Ht. Vs. Wind Velocity

viii) A26ENGY - Calculate and Plot Erosion Energy Vs. WL - Threshold

ix) A26SAND - Annual Mass Curves of Onshore and Longshore Energy

x) A26EROSN - Onshore and Longshore Energy Vs. Level, & Calc. of Effective Lake Levels.

xi) A26DEEP - Summation of deep water Wave Energies.

THE DATA BASE

The data used in the Lake Winnipeg Shoreline Erosion Study is comprised of eight three hour records per day taken every day from May 15 to November 15 for the years 1971, 1972 and 1973. This made a total of 4440 records. Each record contains the date and time of record, recorded and still water levels, and wind and wave information for Gimli and for Grand Beach.

Because of the large amount of data and the many times the data would have to be accessed

throughout the study, card input was completely impractical.

Therefore two disk files were created having the names A26. EROSION and A26 EROS. GF. These two files were manipulated using a "Father and Son" procedure. Each time data was added to or changed in the data base, the old data was read from the "Father File", modified if necessary, and written out on the "Son File". In a subsequent step the "Son File" became the "Father File", and the resulting file was written back on the first file. Using this method the data base was not destroyed if an error was made in making the modification because the data base was preserved in the "Father File". The basic data was loaded from cards onto one of the disk files using the programs A26LOAD and A26FILL. Before any missing data was filled using the regression results a copy of the original data base was put on a tape using the program A26LOAD. Also a copy of the final gap filled data base was copies onto a tape using the program A26LOAD. Also a copy of the final gap filled data base was copied onto a tape. These tapes will be saved for future reference after the study is completed.

DATA BASE GAP FILLING

Many wave records were missing for both Gimli and Grand Beach. Therefore the wave parameters had to be estimated.

WAVE HEIGHTS

Wave height is a function of wind velocity, water depth, fetch length and wind duration. Near the shore the waves are also affected by bottom and shoreline configurations. Changes in wind direction and velocity with time, and over the fetch length greatly complicate the relationship. Therefore, a direct calculation of missing wave height data was not possible. In this study the missing wave height was calculated using regression analysis.

In selecting independent variables to be used in the regression analysis consideration was made of the parameters which affect wave height, and of the availability of the data for those parameters. Of course for a given location and wind sector water depth and fetch length are approximately constant and so need not be included. The variables chosen for consideration in the analysis were wind velocities at Gimli and Grand Beach for the time period being studied and for the previous period. Also the change in wind direction since the previous time period was chosen. The wind velocities for the previous period and the change in wind direction give an indication of the duration and changeability of the wind.

The wind data for Gimli was complete. Therefore this data was the primary independent variable used in calculating missing wave heights. Some wind data was also available for Grand Beach.

There are many ways in which regression analysis can be applied in filling gaps in the data base. The type of regression could be linear or log versus log. All observations could be grouped together, or they can be separated according to months or groups of months and wind directions, or groupings of wind directions. Many combinations of the above were tried in the analysis using the program A26WAVES. The best results were achieved using linear equations grouped into nine separate cases for Gimli and nine cases for Grand Beach.

The nine cases for both locations were made up of three seasons, each separated into three wind sectors. The seasons chosen

were:

1. May to July
2. August to September
3. October to November

The wind sectors for Gimli and Grand Beach are shown in Figure 1. For Gimli two Equations were used in the gap filling process for each of the nine cases. These equations were of the form:

$$H=C+F_1 \cdot VG_i+F_2 \cdot VG_{i-1}+F_3 \cdot VGB_i+F_4 \cdot VGB_{i-1}$$

where

H - Wave Height
C = Regression intercept
F = Regression coefficient
VG = Wind Velocity at Gimli
VGB - Wind Velocity at Grand Beach
i = represents the present observation's value
i-1 = represents the previous observation's value

For Grand Beach the two equations used were

$$H=C+F_1 \cdot VG_i+F_2 \cdot VG_{i-1}+F_3 \cdot VGB_i+F_4 \cdot VGB_{i-1}$$

$$H = C + F_1 \cdot VG_i + F_2 \cdot \text{Cos}\ (\theta_{i-1} - \theta)$$

where θ = wind direction at Gimli.

These equations were used in program A26GPFIL in Filling the gaps in the data base. Equations (1) and (3) were used in all cases where both Gimli and Grand Beach Wind data was available. When only Gimli wind was given Equations (2) and (4) were used.

WAVE PERIOD

Wave period is a function of wave height, wind duration, water depth, and fetch length. The regression analysis for filling gaps in the wave period record was much the same as that used for wave heights. The final form of equation chosen was:

$$T = C + F_1 \cdot H$$

where T = wave period and
H = corresponding wave height.

This is a very oversimplified relationship and the correlations were less than terrific. However, more complex relationships gave no better results. This equation was used at both Grand Beach and Gimli for the same nine cases used in the wave height analysis.

WAVE ENERGY

The deep water wave energy for a first order wave is given by

$$E = \frac{\gamma H^2}{8}$$

where
E = Wave energy in ft. lb/ft^2
γ = Specific weight of water
H = Deep water wave height

This energy is half potential energy and half kinetic energy. The kinetic energy is the energy which will cause the erosion on the shoreline. The wave power which could cause erosion is the kinetic energy times the velocity. For deep water the wave velocity is given by:

$$C = 5.12T$$

Therefore the wave power available for erosion is:

$$P = \frac{E}{2} \times C$$

$$= \frac{\gamma H^2}{2x8} \times 5.12T$$

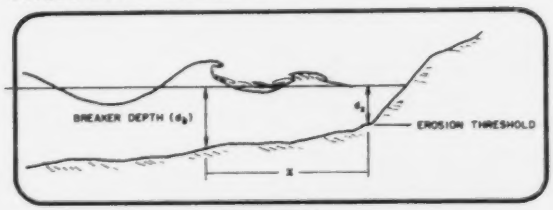
$$= 20.0H^2T \text{ ft lb/sec/ft of wave crest}$$

This value was calculated and loaded in the data bank for each observation at Grand Beach and at Gimli using the program A2620H2T.

ANALYSIS

The object of this study was to determine how a change in Lake Winnipeg's water level regulation pattern would affect the shoreline erosion process. In the previous stages a three year wave climate for two locations on the south end of Lake Winnipeg were produced. These values can now be used as a representative sample for the Lake in estimating erosion.

In order to estimate erosion effects, shoreline erosion had to be tied to the calculated wave energies available for erosion in each time period. A simplified erosion model was assumed in which the beach had a discontinuity above which 100% of the energy would result in erosion, and below which none of the energy would cause erosion. This discrete level was called the "erosion threshold". Any wave energy passing over this erosion threshold would be expended in shoreline erosion. The figure below illustrates this model.



EROSION MODEL

The wave energy remains at the deep water energy until the wave breaks. From that point onward up the flat beach the energy is assumed to dissipate according to the formula

$$E_x = E_o (d_x/d_b)^4$$

where

E_x = Wave energy crossing the erosion threshold

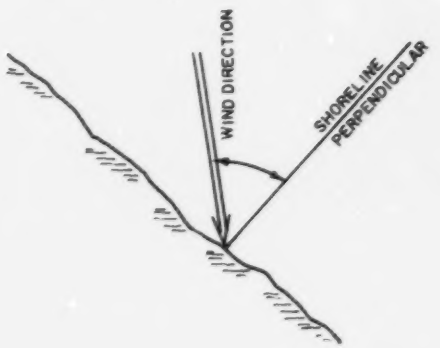
E_o = Deep water wave energy available for erosion

d_x = Water depth at the erosion threshold

d_b = Breaker depth (=1.3 x wave height)

In order to apply these results to various water level regimes a plot of water level above the erosion threshold versus erosion energy was made for each month and each wind sector shown in Figure 1. For a particular wave energy read from the data bank, twenty corresponding erosion energies were calculated for twenty different values of water level minus erosion threshold. This was done using program A26ENGY. Then for a given water level duration curve the total energy causing erosion could be calculated for each month and wind sector. A comparison of the results for different modes of regulation would indicate the comparative erosion to be expected for each case. However the energy curves were difficult to apply to the various reaches being studied. Therefore the method was modified to produce seven monthly curves for each reach rather than for each wind sector.

The figure below shows the approximation made in dividing the erosion energy into onshore and longshore components.



The wave direction is assumed to be parallel to the wind direction. Only the perpendicular component of the energy will cause erosion. This then is E cos θ. Then some of this energy will cause onshore erosion, and some will cause longshore erosion.

Therefore these two components can be given by:

$$E_{onshore} = E \cos^2 \theta$$

$$E_{longshore} = E \cos \theta \sin \theta$$

The calculations of onshore and longshore components of energy are made in program A26EROSN. For each reach read in, curves of longshore energy causing erosion versus water level minus erosion threshold and onshore energy causing erosion versus water level minus erosion threshold are calculated. Seven monthly curves are calculated for each reach. As in program A26ENGY, the curves are derived assuming twenty-five different values of water level minus erosion threshold for each wave observation in the month.

Step two of A26EROSN uses these derived curves to make the final comparison of erosions to be expected under different modes of regulation. Seven monthly water level duration curves are read in for each of three modes of regulation - Recorded conditions, Modified Historic conditions, and Regulated conditions. Using these levels, the mean monthly onshore component of erosion energy for each month at a given reach can be calculated for the three modes of regulation. For ease of comparison an effective mean monthly level is computed for each case. (This is a constant level the water would have to be at during the month to result in an equivalent amount of erosion).

Programs A26SAND and A26SHORE were developed to test the erosion model quantitatively. IN A26SAND the erosion energy which would be expected from the recorded levels was summed for each observation having a wind direction within the specified sector. One curve was drawn for each year. In effect, these were mass curves of power, or summations of energy causing erosion during the year. Program A26SHORE was a modification of A26SAND to break the energy into onshore and longshore components. Also in A26SHORE all three years were plotted together. These curves were developed for reaches where rates of erosion have been measured over the past three years. The comparisons indicate that the results of this study can give qualitative comparisons of erosion under different modes of regulation, but any attempt to derive quantitative erosion rates would give results of questionable accuracy.

Program A26DEEP was developed to give a summary of deep water wave energies in the data bank. The energies are summed according to wind direction and month.

COMMENTS

The analysis used to fill the gaps in the data base is the best that can be done with the amount of data given. However some of the correlations, particularly on the East Shore where some of the wind data is missing, are not as good as would be desired. Considering what this data was used for, though, this is not a major problem. What was important for this study was to get a representative wave climate for the south pool of Lake Winnipeg. The hour to hour and day to day variations in this climate were not important. This gap filling process did give a good representative wave climate for the lake. In other words, we could not necessarily give an accurate estimate of the wave height at Grand Beach at three o'clock in the morning on July 16, 1971, but we could give a good mean and standard deviation of the wave heights during the month.

The model used in relating erosion to wave energy is a large oversimplification. More complex analysis would include a gradual change in the proportion of the energy that

causes erosion with change in beach slope rather than a single discontinuity. This single point discontinuity made the analysis overly sensitive to the somewhat arbitrary selection of the erosion threshold level. A further refinement of the analysis would include the frequency analysis of the entire wave train, rather than just using the equivalent wave height and its associated energy. Furthermore using $\cos^2\theta$ and $\cos\theta.\sin\theta$ in calculating onshore and longshore components of energy could result in significant errors. The refraction of the waves near the shore and the associated reduction of wave heights can only accurately be estimated using a refraction analysis for each wind direction at every reach.

Of course, if all of the preceding refinements had been included this study would have taken much much longer to complete and would have been far more costly. Time and budget limitations required a simplified approach. The study approach, then, is valid and gives meaningful results as long as the interpreter of the results keeps in mind the simplifications involved. The use of the results to indicate whether erosion will increase or decrease under a new mode of regulation is valid.

ANNEX 3

EVIDENCE FOR RECENT ISOSTATIC REBOUND IN MANITOBA

Isostatic rebound is a phenomenon in which the earth's crust, after having been deformed by the weight of the glaciers during the last ice age, is slowly rising back to its pre-glacial position. There is considerable evidence which indicates that isostatic rebound is occurring in the area around Hudson Bay.

Using dated raised marine deposits Andrews (1970) constructed post glacial isobases for the Hudson Bay area. Isobases are lines that connect points undergoing equal rates of uplift. Gravity anomaly curves show that the area is over-compensated for the weight of the glaciers it supported at one time and it should continue to rise until it has once again achieved isostatic equilibrium (Walcott, 1970). Work done by Kite (1972) based on lake level measurements indicate that the Great Lakes area is currently undergoing uplift. The isobases derived by Kite (1972) have been extrapolated to the northwest into the Lake of the Woods area by code (1972) to agree with water level gauge data there. Using elevations from ancient Lake Agassiz beaches Johnston (1946) found that the beaches were higher to the north and attributed this to isostatic rebound. All these sources indicate that isostatic rebound is occurring and that its direction of maximum tilt in the Manitoba region is to the northeast towards Hudson Bay.

By further extrapolating Kite's (1972) isobases into Manitoba's possible average direction of maximum tilt perpendicular

to the isobases was determined as is shown in Figure 1. The tilt pases through The Pas and midway between Churchill and York Factory. That this line actually follows a trend of increasing uplift is demonstrated by Figure 2 which was constructed from Walcott's (1970) gravity anomaly curves and from King's (1965) past uplift curves based on raised lacustrine and marine beaches.

Once a line of maximum tilt was established the next step was to calibrate it with uplift rates. The simplifying assumption was made that the entire Manitoba region is rebounding as a plane. The zero isobase was chosen as the line perpendicular to the maximum tilt direction at the point where Kite's (1972) extended zero isobase intersects it.

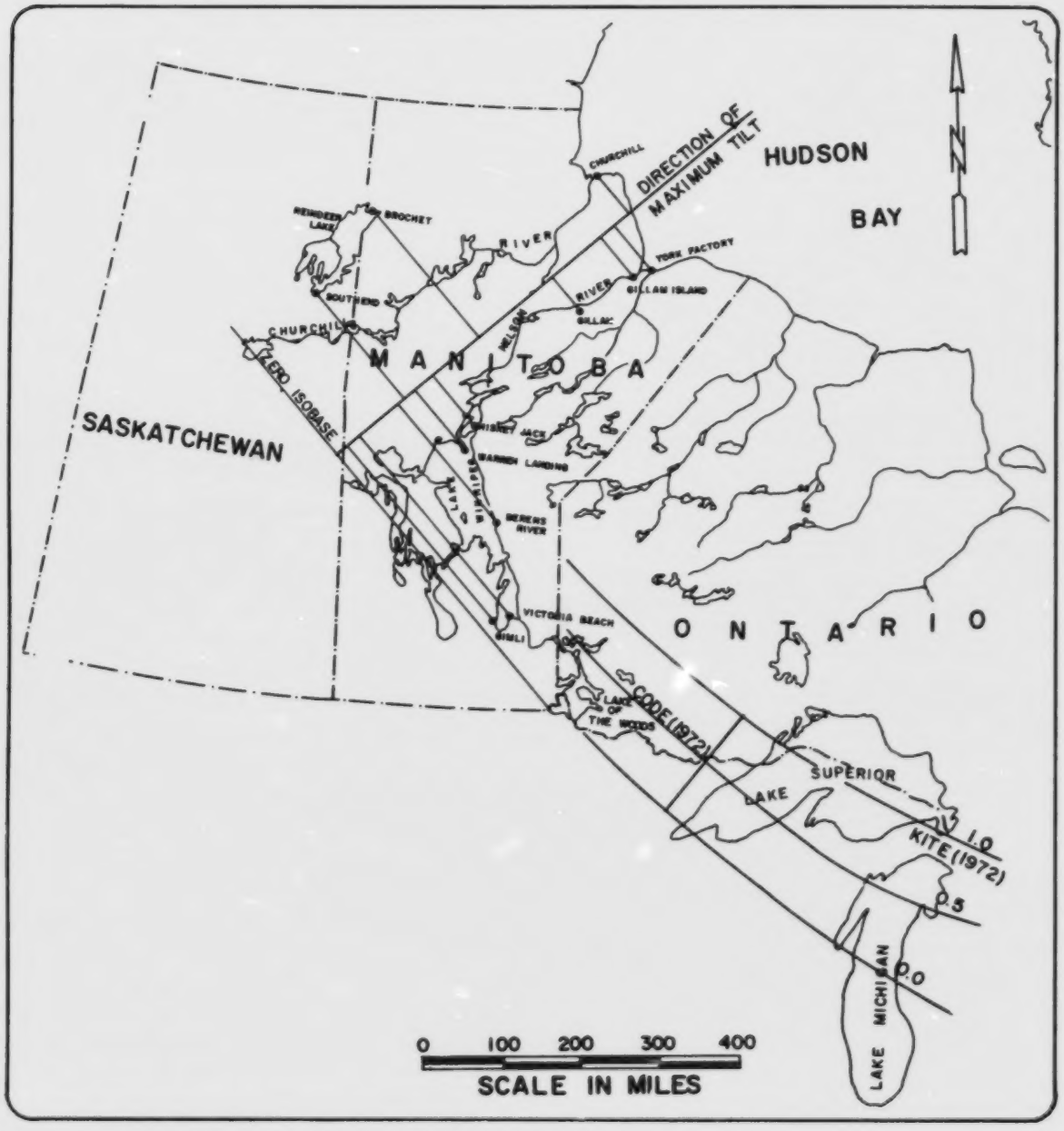


Figure 1 Map Showing Assumed Direction Maximum Tilt in Manitoba

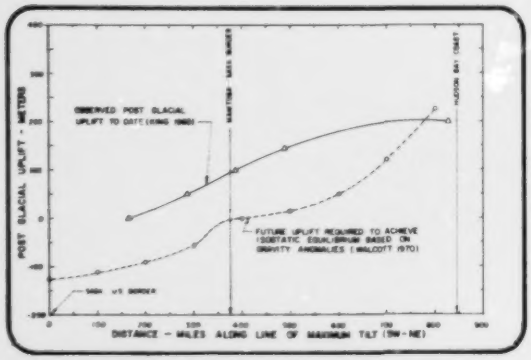

POST GLACIAL UPLIFT - METERS
OBSERVED POST GLACIAL UPLIFT TO DATE
FUTURE UPLIFT REQUIRED TO ACHIEVE ISOSTATIC EQUILIBRIUM BASED ON GRAVITY ANOMALIES (WALCOTT 1970)
DISTANCE - MILES ALONG LINE OF MAXIMUM TILT (SW - NE)

Figure 2 Pattern of Uplift Along Line of Maximum Tilt.

Analysis of the tide gauge data at Churchill from 1940 to 1968 indicates that the area is rising at a rate of about 1.75 feet per 100 years (Barnett, 1970). A graph based on Craig's (1968) carbon-dated marine shells in the Churchill area shows that uplift occurred more rapidly immediately following the retreat of the ice sheet and is proceeding at a gradually decreasing rate (See Figure 3). Simpson (1972) had samples of ancient driftwood in the York Factory area dated. Analysis of his data indicates the area is currently experiencing an uplift rate of 1.40 feet per 100 years.

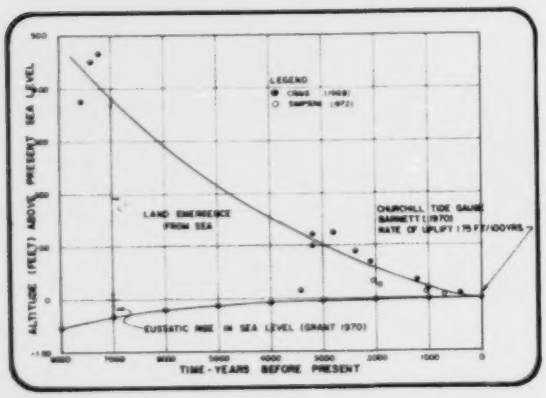

ALTITUDE (FEET) ABOVE PRESENT SEA LEVEL
LEGEND
LAND EMERGENCE FROM SEA
CHURCHILL TIDE GAUGE
EUSTATIC RISE IN SEA LEVEL (GRANT 1970)
TIME - YEARS BEFORE PRESENT

Figure 3 Post Glacial Uplift In The Churchill Area Derived From Radiocarbon Dates on Marine Shells (Craig 1968) And Driftwood (Simpson 1972).

Figure 4 was constructed using the average of the Churchill and York Factory uplift rates and assuming a linear increase from the zero isobase. This model gives an uplift difference between Gimli and Berens River of 0.27 feet per 100 years. Analysis of the levels of Lake Winnipeg for Gimli and Berens River between 1914 and 1971 for the winter months indicates Berens River may be rising relative to Gimli at a rate of 0.22 feet per 100 years. Similar analysis for the summer months gives an uplift difference of 0.14 feet per 100 years. Although these figures are somewhat lower than the rate predicted by the model, it should be pointed out that the standard deviations for the winter and summer data are 0.134 feet and 0.194 feet respectively. There is, therefore, considerable margin for error in the values quoted. It's also possible that the rebound rate does not increase linearly along the line of maximum tilt but exponentially. This would give a predicted uplift difference between Gimli and Berens River that is closer to the observed difference and would also fit the Churchill-York Factory data better. Because of the scarcity of information, the fitting of such a curve would be almost entirely subjective and the linear approach has been retained as an adequate approximation.

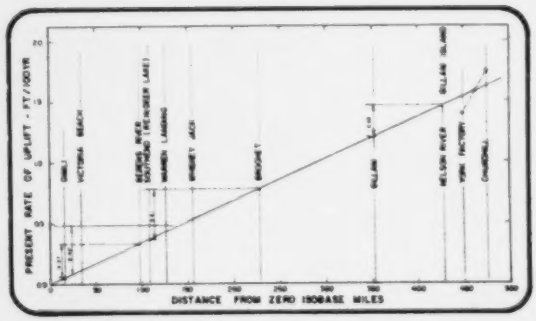


Figure 4 Present Rates of Uplift

Figure 4 shows that Lake Winnipeg's outlet (Whiskey Jack-Warren Landing) may be rising

relative to the south end of the lake at a rate of 0.40 feet per 100 years. Using data from Figures 3 and 4, Figure 5 was constructed. It demonstrates the advance of the lake over the land at its southern end as the outlet uplifted. This is based on the assumption that the outlet is non-erodible. This is a valid assumption as the outlet at Whiskey Jack Narrows is bedrock controlled. Also shown on the graph is the average of carbon dates from a peat sample taken near Victoria Beach. The top of the sample (704 feet a.s.l.) was formed 1060$^{+}_{-}$210 years BP (GSC 1980) and the bottom (703 a.s.l.) is 1660$^{+}_{-}$60 years old (GSC 1977). Dr. John Stewart (1974) felt confident the peat was formed in situ.

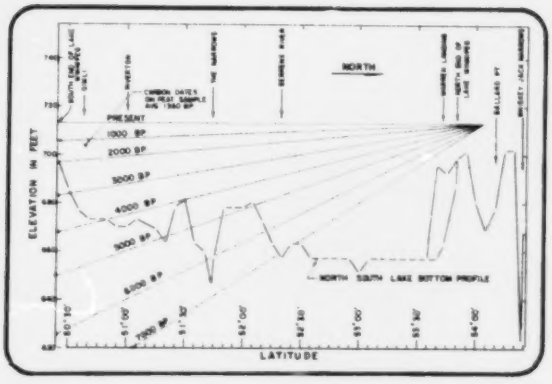


Figure 5 Conjectural Water Planes For Lake Winnipeg (Based on Data From Craig 1968)

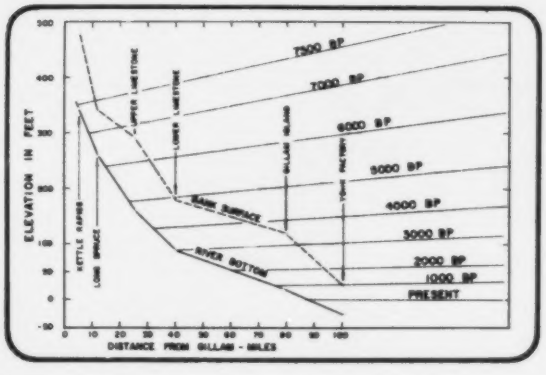


Figure 6 Conjectural Water Planes in Hudson Bay Based On Carbon Dated Marine Shells (Craig 1968)

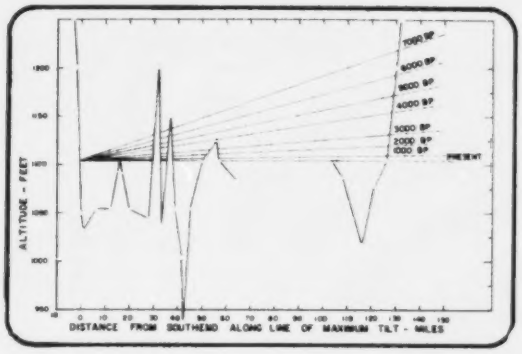


Figure 7 Conjectural Water Planes For Rendeer Lake Based On Carbon Dated Marine Shells (Craig 1968).

Gillam Island is currently rising with respect to Gillam at a rate of 0.26 feet per 100 years according to Figure 4. The drop of Hudson Bay water level relative to the land surface over the past 7500 years is demonstrated in Figure 6.

The model predicts that the northern end of Reindeer Lake at Brochet is rising relative to its outlet at south end at about 0.41 feet per 100 years. Figure 7 illustrates how the northern shoreline has moved southwards as rebound proceeded. In the case of Reindeer Lake there is evidence that the outlet has been eroding and that water level changes due to downcutting of the outlet may exceed those due to isostatic rebound. Thus, the phenomenon of isostatic rebound may have a significant effect on the lower Nelson River and on long term shoreline processes of both Lake Winnipeg and Reindeer Lake.

In summary, evidence from several sources indicates that the pattern of isostatic rebound in the Manitoba region is towards Hudson Bay with the direction of maximum tilt being from southwest to northeast. An average line of maximum tilt was chosen and

a linear increase in uplift rate was assumed towards the northeast. The line was calibrated using the average uplift rate from Churchill and York Factory. Based on the assumption that the entire area is being tilted as a plane, the model was used to predict the difference of uplift rates between Gillam and Berens River, with a fair degree of accuracy. There was some indication that the rebound rates may be increasing exponentially towards Hudson Bay but the data was considered too sparse to attempt fitting such a curve. Conjectural water plane graphs from about 7000 BP to the present were drawn from Lake Winnipeg, the Lower Nelson River, and Reindeer Lake showing the effects of isostatic rebound on water levels in these areas.

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ANNEX 4

VERIFICATION OF EROSION MODEL

For the purpose of computing the effect of lake level on shoreline recession, it was assumed that shoreline recession was porportional to the wave energy where such energy was computed according to the procedures outlined in the methodology of the text. In order to verify that shoreline recession is proportional to wave energy, the historic recession observed at a number of profiles over a period of up to 95 years was correlated with the wave energy. It was also assumed that the hydrologic base period of 1928 to 1966 represents the hydrologic conditions from 1876 to 1950 for computing the wave energy impinged on a shoreline in a reach. From 1950 to 1971 mean monthly water levels were used to compute the wave energy impinged on a reach.

Correlations at three profiles were performed and at two cross-sections a series of erosion threshold elevations were correlated with the wave energy calculations. The results of the correlations are shown on Figures 1 and 2. The assumed erosion threshold elevations at profiles 031 and 163 indicate lower correlations with wave energy than the actual erosion threshold selected from the profile the correlations with wave energy pass through the origin and appear to be reasonable.

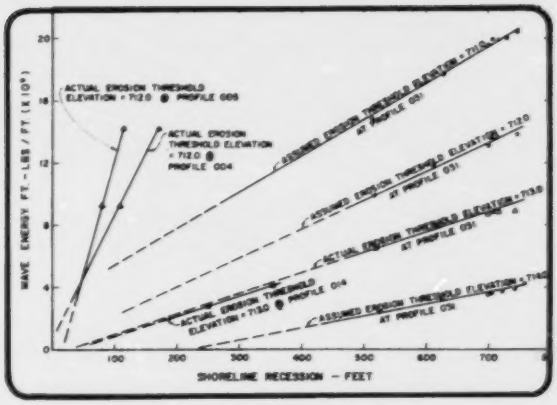
WAVE ENERGY FT.-LBS / FT (X 10³)
SHORELINE RECESSION - FEET
ACTUAL EROSION THRESHOLD ELEVATION = 712.0 @ PROFILE 005
ACTUAL EROSION THRESHOLD ELEVATION = 712.0 @ PROFILE 004
ACTUAL EROSION THRESHOLD ELEVATION = 713.0 @ PROFILE 014
ASSUMED EROSION THRESHOLD ELEVATION = 712.0 AT PROFILE 031
ASSUMED EROSION THRESHOLD ELEVATION = 713.0 AT PROFILE 031
ACTUAL EROSION THRESHOLD ELEVATION = 713.0 AT PROFILE 031
ASSUMED EROSION THRESHOLD ELEVATION = 714.0 AT PROFILE 014

Figure 1 Correlation Of Erosion Threshold Versus Wave Energy Erosion.

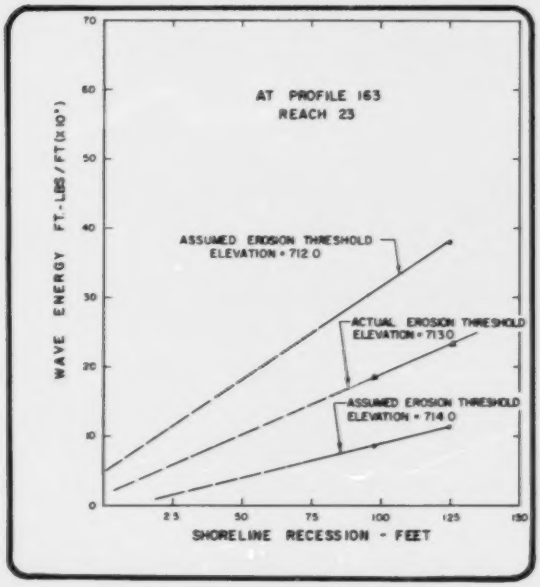
AT PROFILE 163
REACH 23
WAVE ENERGY FT.-LBS / FT (X 10³)
SHORELINE RECESSION - FEET
ASSUMED EROSION THRESHOLD ELEVATION = 712.0
ACTUAL EROSION THRESHOLD ELEVATION = 713.0
ASSUMED EROSION THRESHOLD ELEVATION = 714.0

Figure 2 Correlation of Erosion Threshold Versus Wave Energy Erosion.

APPENDIX 2 - VOL. 1 - C

ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE AND 2-MILE CHANNELS

ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE AND 2-MILE CHANNELS

by

A. BARACOS and V. GALAY
Department of Civil Engineering
University of Manitoba
Winnipeg, Manitoba
July, 1972

sub-contracted by:

Planning Division, Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

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2. Cutter head and suction pipe of dredge.

3. Spare 42 inch delivery pipe stock piles at entrance to 8-Mile Channel.

4. Slumping banks at entrance to 2-Mile Channel.

5. Fine sand deposits at entrance to 8-Mile Channel.

6. Route of 8-Mile Channel. Entrance to channel is at top of photo, Kiskittogisu River is in foreground.

LIST OF PLATES

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II - 2-Mile Channel - Topography

III - 8-Mile Channel - Dredge Spoil Area

IV - Ominawin Bypass Channel - Topography

V - 2-Mile Channel - Reference Line Profile

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VII - Dredge-Spoil Deposits Summary

VIII - Side Slope for Deep Cut in 2-Mile Channel

IX - Velocity Duration Curves

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The cooperation of the following Manitoba Hydro engineers is gratefully acknowledged:

Hydraulics - H. Hopper, W.K. Mann and W. Veldman

Geotechnical - K. Vogel and D. Gould

The following Manitoba Hydro tendering specifications were used throughout this report:

Specification No. 756 - Construction of 2-Mile Channel and 8-Mile Channel

Specification No. 846 - Construction of Ominawin Bypass Channel

Information regarding the behaviour of the channels was also obtained from the following report prepared for Manitoba Hydro:

"Shoreline Processes Along the North Shore of Lake Winnipeg and In Playgreen and Kiskittogisu Lakes" - by V. Galay. Report to Manitoba Hydro, September, 1971.

INTRODUCTION

The plans and specifications prepared by Manitoba Hydro for the construction of the 2-Mile, 8-Mile and Cminawin Bypass Channels of the Lake Winnipeg Regulation Project were studied (see Fig. 1 for location) in order to provide data describing changes to the physical environment resulting from construction in order that other resource disciplines may properly assess the effects on the environment.

Part A of this report summarizes the data with regard to the immediate effects of construction, and constitutes Phase 1a of the Study Proposal. Discussed in this part are: the physiography of the spoil areas, the nature of the material to be removed from the channels, several aspects in regard to dredging and the proposed effluent controls and possibilities of vegetation on the spoil areas. The Cminawin Bypass Channel, which is to be constructed by dragline and scraper, is not discussed in detail in Part A since the control of effluent will not be a problem.

Part B summarizes data with regard to the effect from operating the channels, and constitutes Phase 1b of the Study Proposal. Discussed are some aspects regarding erosion and stability of the channel banks, and erosion and deposition from the channel operation.

PART A - DREDGE SPOIL STUDIES

ASPECTS OF DREDGING

The removal of 35 million cubic yards of clay from the 2-Mile and 8-Mile Channels will be accomplished by dredging over the coming three summers. The material in the Ominawin Bypass will be excavated by scraper and dragline.

A specially designed dredge has been assemblied for this contract (by Sceptre-Dillingham Ltd.) and has a rating of 5,000 hp. at the cutter head and 10,000 hp. for the pipeline. Illustrations of the dredge and pipeline are shown in Photos 1, 2 and 3. The suction and delivery pipe, which can be up to 10,000 feet in length, are both 42 inches in diameter.

The dredge will remove an average of 3,600 cubic yards of material per hour. The maximum water capacity of the pumps is some 4.5 million gallons per hour (or 27,000 cubic yards per hour). The exact percentage of solids to water that will be pumped is difficult to estimate. A leading dredging consultant has stated (Huston, 1967), "So little has been done in this field that dredgemen can do little more than guess at the amount of percentage solids."

The material excavated by the dredge will, for the most part, consist of a stiff clay which should "ball" when passing through the pipeline. The cutter head is expected to remove the clay in discrete lumps which may not break up when passing through the pump and pipeline. As stated by the contractor (Winnipeg Free Press, October, 1971) - " ... the pumps should be able to pass an 18 inch cannonball." This "balling" of clay should result in a rapid settlement of the material in the spoil area and greatly reduced volumes of solids in the effluent.

MATERIALS TO BE DREDGED

The materials encountered along the 2-Mile and the 8-Mile Channels are shown in detail on Plates V and VI. Based on interpolation of these figures the materials may be classified as shown in Table I.

Table I

APPROXIMATE PERCENTAGE OF TOTAL, OF MATERIALS ALONG CHANNELS*

	Material	Percent
2-Mile Channel	Clay	87
	Peat	12
	Silt, Sand, etc.	1
		100
8-Mile Channel	Clay	58
	Peat	29
	Silt, Clay Silt & Sandy Clay	7
	Sand	4
	Bedrock	2
		100

*As measured along centre line profile

a. Clay

Tests by Manitoba Hydro classify the clays as CH, CI and CL. These terms denote respectively clays of high, medium and low plasticity. The clays are cohesive as shown by unconfined compression strengths ranging from about 730 to 2500 psf. A consequence of this cohesion, is that during dredging, the clay will tend to be cut in chunks and pass through the dredging system in more or less intact "balls", which settle almost instantly when ponded. Since the clays contain up to 50 percent of material finer than 0.002 mm, which can stay in suspension as individual particles, it is highly desirable that the "balling" action take place.

It should also be noted that after deposit in the spoil areas, the dredged clay will be highly compressible and much weaker than in the undisturbed

state. This condition will exist because of the voids between the deposited clay balls, and the high moisture content of the deposited material.

b. Peat

Limited data for the peat indicates that its unit weight is about, or slightly exceeds, that of water. There may be a tendency for some peat to float. The data also indicate high void ratios of 10 to 12 which correspond to high permeabilities.

The problem of flotation when it occurs can be alleviated by controlling where the dredge discharge is made. If the dredged peat is discharged on peat covered areas the peat cover can act as an underdrain and filter. Removal of the water through underdrainage would prevent floatation.

c. Silt, Sand, Etc.

These are coarser materials which would have relatively rapid settling velocities when ponded. They constitute relatively small percentages of the materials to be dredged.

CHARACTERISTICS OF SPOIL AREAS

The locations of the channels and spoil areas defined by dykes and high land are shown on Plates II, III and IV respectively for the 2-Mile, 8-Mile and Ominawin Channels. The plates also show the 1000 foot wide limits beyond which sedimentation is not allowed to take place in Playgreen Lake from dredging operations on the 2-Mile Channel, and in Kiskittogisu Lake from dredging on the 8-Mile Channel.

a. 2-Mile Channel

The spoil area extends 10,000 feet to either side of the channel with dykes along the boundaries. Surface flow is towards Playgreen Lake. There is appreciable peat cover which can serve as an underdrain. The maximum depth of cut for the channel exceeds 52 feet and from station 0+00

to 100+00 W averages about 40 feet. The greater depth of cut introduces more severe stability considerations for the side slopes of the channel. These considerations have been acknowledged in a modified design which incorporates less steep slopes and a berm as shown on Plate VIII. The location of spoil areas is not a consideration, as no spoil areas are planned adjacent to the deepest cut. Photograph 4 shows the unstable bank conditions fronting Lake Winnipeg. Desirably, the spoil limit here has been kept 1000 feet from the lake edge.

b. 8-Mile Channel

The spoil limits for the 8-Mile Channel consist of approximately 50 square miles, as shown on Plate III. Two practical considerations impose further limitations.

(1) The height of land.

It is more economical to have a minimum lift of dredge material. Table II summarizes the type of area to be covered in relation to elevation (also see Photo 6).

Table II

8-MILE CHANNEL SPOIL AREA

RELATING ELEVATION AND EXISTING COVER

Elevation	Type of Cover	Approximate Area in sq. miles
below 710	water	3
710-715	mostly swamp	19
715-720	swamp and low shrub	20
720-725	bush and swamp	5
above 725		3
	Total	50

(2) Proximity

Provision has been made for pumping up to 10,000 feet horizontally from the channel. Short distances are more economical if all other factors are equal. Except for the first half mile which is high, it will be noted that the discharge within 5000 feet of the channel will be on areas below elevation 715. It is therefore likely that the principal areas to take spoil will be relatively low and presumably either covered with water or peat.

The discharge of peat on peat is desirable because of the underdrainage effect which can prevent flotation. Clay and other materials discharged on peat will result in compression of the peat, which could reduce its thickness to less than half of its present thickness. It is understood the peat is acidic and it is theoretically possible that this will aid in the flocculation of any clay. Flocculation increases the rate of sedimentation of clays.

The sedimentation of spoil in water, particularly of fine grain soils in suspension, requires a period of ponding in relatively still water. The sequence of constructing dykes and filling can be used to provide a period of ponding and sedimentation to take place.

CONTROLS OF EFFLUENT FROM SPOIL AREAS

The spoil areas and their characteristics have already been discussed. The effluent from the spoil areas will slowly make its way from the end of the pipeline to the spillway or pipes at the lower levels of the spoil areas. The approximate location of these outlets are shown on Plates II and III. The exact type of structures to release the effluent from the spoil areas has been left up to the contractor. Manitoba Hydro has specified that the

sedimentation of solids from the effluent after ponding shall be restricted to within 1000 feet from the shoreline. These sediment deposition areas are shown on Plates II and III. If deposition is excessive beyond these areas the contractor will have to remove the deposited material at his own expense. The exact means of monitoring the deposition is being investigated by Manitoba Hydro.

With the concern for increased environmental controls it is natural that various disciplines and the public would request that turbidity limitations be established. At present there is no one acceptable value of turbidity (Huston, 1970). Turbidity limitations depend upon many factors, but the consideration for the fishes' natural environment is usually the most important factor. The limitations vary widely, from 6,500 parts per million (ppm) to 100,000 ppm as determined from laboratory research. In regard to the turbidity to be expected due to the dredging of the 2-Mile and 8-Mile Channels all we can do now is to indicate a maximum turbidity if the dredge discharged directly into the main flow channel of the Nelson River. It is beyond our capabilities to predict the consequence of this maximum level of turbidity.

An approximate estimate of the maximum possible level of turbidity is based on the following assumptions:

1. The average dredged volume of solids (3600 cu. yd./hour) is discharged directly into the main flow channel of the Nelson River without ponding.
2. The average flow in the Nelson River during the coming summers will not be less than 100,000 cfs.

Therefore, if the dredge hypothetically discharged all of the excavated material into the main flow of the Nelson River the concentration

of solids would be approximately 400 ppm. The present turbidity of the Nelson River varies widely and may be up to 70 ppm. Due to settlement in the spoil areas, however, concentrations should not reach 400 ppm. There may be local concentrations of solids higher than 400 ppm. if the spoil effluent discharges into a still water area. Any high concentrations will probably be dispersed once the dredged channels are opened and fully operational.

FUTURE DEVELOPMENT OF SPOIL AREAS

The spoil areas adjacent to the 2-Mile Channel are treed with black spruce. Dredged clay will be pumped into the areas with the result that the trees will die off. Once this occurs it may be possible to remove the dead trees, level the area with bulldozers and plant small shrubs or some type of grass. The manner of clearing this area after deposition of solids is still, however, not clearly set out.

The spoil areas adjacent to the 8-Mile Channel are swampy with low shrub grass. The intention of Manitoba Hydro is to redevelop these areas after consultation with forestry, soil science and wildlife officials.

The spoil area south of the Ominawin Bypass will be easier to deal with as excavation is by conventional means and dumping of material can be easily controlled.

SUMMARY - PART A

A summary of the dredge spoil areas, the properties of the excavated materials, and controls on the effluent are presented concisely on Plate VII. These findings are as follows:

1. The dredge spoil areas for the 2-Mile and 8-Mile channels are more than adequate in size to retain the excavated channel material.
2. The dredged material from the 2-Mile and 8-Mile Channels will be predominantly clay.
3. It is anticipated that the clay will emerge as distinct chunks ("ball") from the pipeline. The "balling" of the clay cuttings will depend upon the operation of the dredge. The clay "balls" should settle instantly.
4. Dykes will be used to confine the dredged material within the designated spoil areas. Effluent outlets will be located at the lower end of the spoil areas and the deposition of solids in the lakes is limited to within 1000 feet from the effluent outlets and shore.
5. A hypothetical maximum level of turbidity of 400 ppm would occur if no controls were placed on the dredging. The present natural turbidity in Playgreen Lake has been up to 70 ppm.
6. The Ominawin Bypass Channel is to be excavated by dragline and scraper and should pose no problems in terms of effluent control.

PART B - ASPECTS OF CHANNEL OPERATION

CHANNEL SIDE SLOPES

a. Slope Stability in Cuts

Manitoba Hydro has used a safety factor of at least 1.5 in the design of the side slopes of the channel to preclude sliding. The geometries of the side slopes have been selected as shown on Plates V, VI and VIII, to give this safety as based on soil strength parameters obtained from an extensive test hole drilling program, and laboratory tests. It must, however, be realized that in a project of such magnitude it is impossible to completely eliminate the possibility of some sections of the side slopes from undergoing future movements, in some cases occurring many years after the completion of the work. This has to be recognized as part of a maintenance program. Considering the 400+ foot base width of the channels and noting that the major portion of the deep cuts are in clay, the consequences of such movements should be negligible as far as contributing sediment to the channel flow.

Features incorporated in the design to give the design safety factor of 1.5 include:

1. Less steep side slopes where deep cuts are involved. Plate VIII shows the 5:1 (horizontal to vertical) for the deepest cuts in the 2-Mile Channel. In comparison, for the less severe conditions of shallow cut and below water, slopes no steeper than 2.5:1 are used.
2. Spoil disposal is to be kept at least 80 feet from the top of the cut. The side slope of the spoil is specified as 3:1.

3. The use of berms. A 30 foot berm, (horizontal ledge) has been incorporated in the slope where peat or other weak material overlies clay. A 30 foot berm has also been introduced in the deepest clay cuts enccuntered in the 2-Mile Channel.
4. The conservative assumption that one of the strength parameters, namely the effective cohesion of the clay, is of negligible magnitude. The strength of the clay has been based on an effective angle of internal friction of 24 degrees, with no allowance for any long term reduction.

b. Dredge Steps

Dredging will produce a stepped side slope below the water elevation as shown in the inset figures on Plate V and VI. Two or three dredge steps with vertical faces are shown. This feature anticipates local sloughing as the vertical faces collapse. The steps are limited in height and so located, that after sloughing the slope should approximately conform to the neat line. The sloughing will result in some soil going into suspension during construction or soon after the channels become operative. Material in suspension during construction operations will move with the water used for dredging on to the spoil areas. The quantities remaining after the channels are in operation should be relatively small and probably quickly removed.

c. Weathering of Side Slope

Manitoba Hydro has specified that the channel side slopes above the water line be protected by vegetation to prevent erosion from rainfall and snow melt. It is not possible to predict what quantities of soil will be moved by such erosion, but a noticeable discoloration of water along the edge of the channel after rain, etc., would likely occur until such time as the vegetation gives protection.

d. Wave Erosion

Erosion of the channel slopes within the channel itself due to wind waves should not constitute a serious problem. However, erosion of the slopes at the entrance to the 2-Mile Channel will take place. Here, waves up to five feet in height due to south winds over Lake Winnipeg may ride up and break on the slopes. This dissipation of wave energy may result in the removal of material in the vicinity of the water-line and eventual instability of the upper part of the slope. This removed material, being clay, will go into suspension and will be carried down the Nelson River system. Some of the Clay may settle out in large ponded areas, upstream of the Jenpeg Control Structure.

e. Fill Side Slopes

A special case of side slopes consisting of fill material occurs where the 8-Mile Channel is located within the channel of the Kiskittogisu River. Parts of the side slopes will be formed by dykes that will also retain the spoil material. Close cooperation will be required between design engineers and the contractor to ensure that material placed for the dykes meets the requirements for erosion resistance and stability. The exact technique of dyke construction has not been specified, therefore, the final cross-section of the dykes is unknown. Future protective measures may be deemed necessary if the side slopes do not have the required erosion resistance and stability after some period of operation.

f. Peat Side Slope Protection

Peat occurs at low elevation along the 8-Mile Channel. Specifications call for capping the peat with clay where it occurs below the water level in the channel by dragline dumping. This protection is considered necessary to prevent erosion of the peat.

CHANNEL DESIGN VELOCITIES

The choice of a reasonable allowable velocity for unlined cohesive channels depends on many factors. The procedure followed by Manitoba Hydro is common in engineering practice and involved three stages:

1. assessment of current literature on the subject,
2. undertaking laboratory flume tests to evaluate limiting velocities or limiting tractive forces on clay samples from the actual project, and
3. assessment of the behaviour of existing channels in similar material.

Following these three stages the design velocities arrived at are:

median flow condition = 2.0 ft/sec
historic or 100 year flood = 4.3 ft/sec

These velocities appear to be reasonable in view of the nature of the channel material. Several factors working in favour of the channel may also be worth mentioning:

1. The channel will always contain water, therefore there should be no wetting and drying of the channel surface. Wetting and drying usually results in a loose, friable surface (4 to 8 inches) which is easily removed by flowing water.
2. The channel will not undergo cycles of freezing or thawing since it is to have a flow depth of at least 25 feet throughout the year. Freezing and thawing occurs with many channels in Southern Manitoba resulting in a reduction in stability of surface materials.

The duration or percentage of time that various flow velocities will take place in the various channels is shown in Plate IX. It would appear that the high velocities occur rather infrequently.

During high south winds, wind set-up will result at the north end of Lake Winnipeg which could lead to velocities of 6 to 8 feet per second. in the 2-Mile Channel. This will be a transient phenomena. It is difficult to estimate the extent of channel erosion that may take place with these velocities but the eroded material, being predominantly clay, will probably be carried quite long distances along the Nelson River (possibly to the Jenpeg Forebay or the Kelsey Reservoir). Deposition of this material will probably not be extensive.

The design velocities previously quoted also apply to the Ominawin Bypass Channel. The bed of this channel has several large bedrock outcrops which will prevent major erosion. Some local erosion of the bed directly below the outcrops may take place but this should not be excessive.

SUMMARY - PART B

Several important aspects in regard to channel operation are as follows:

1. Erosion of the slopes at the entrance of the 2-Mile Channel, due to high waves on Lake Winnipeg, may be serious and may reduce the stability of the upper part of the slope.
2. No problems are anticipated with the deep cuts in the 2-Mile Channel.
3. The design velocities used in the three channels appear conservative in terms of accepted engineering practice.
4. Some erosion may take place at the lower end of the 2-Mile Channel when excessive wind set-up occurs on Lake Winnipeg. This will, however, be for short durations of time and may not pose serious problems.
5. Erosion of the fill side slopes at Kiskittogisu River along the 8-Mile Channel may take place depending upon the manner of dyke construction.
6. Erosion along the Ominawin Bypass Channel should not constitute a serious problem as much of the channel is controlled by rock outcrops.
7. Any material eroded from the channels will, for the most part, be clay and will deposit in regions of still water such as the Jenpeg Reservoir and the Kelsey Reservoir.

REFERENCES

Huston, J. (1967) - "Dredging Fundamentals", Proc. ASCE, Vol. 93, No. WW3 August.

Huston, J. (1970) - Hydraulic Dredging, Cornell Maritime Press, Inc., Cambridge, Maryland.

Photo 1

General view of cutter end of dredge.

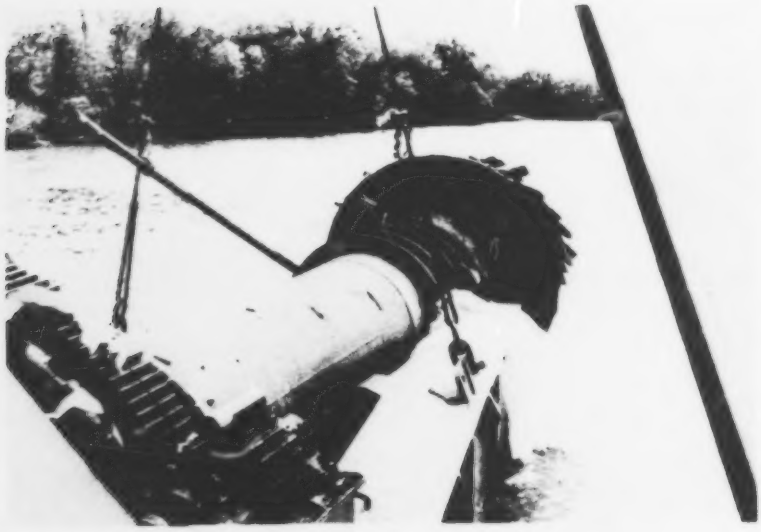


Photo 2

Cutter head and suction pipe of dredge.

Photo 3

Spare 42 inch delivery pipe stock piles at entrance to 8-Mile Channel.

Photo 4

Slumping banks at entrance to 2-Mile Channel.

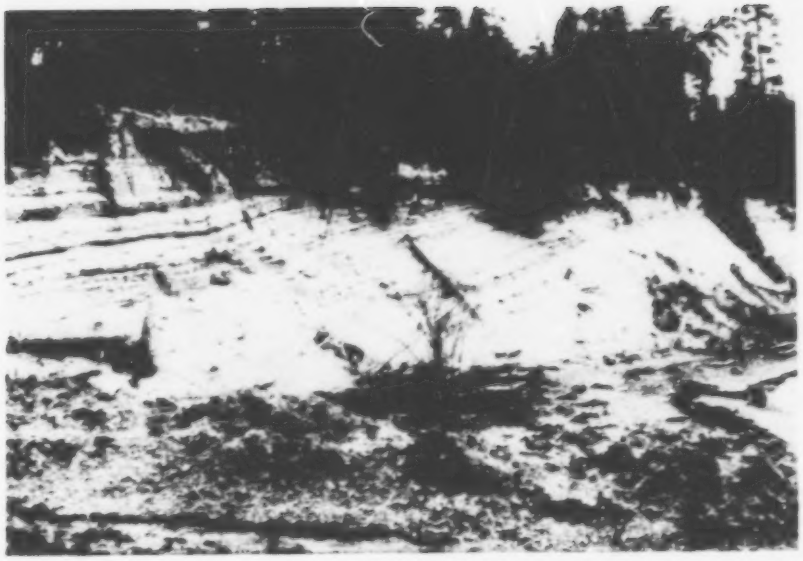


Photo 5

Fine sand deposits at entrance to 8-Mile Channel.

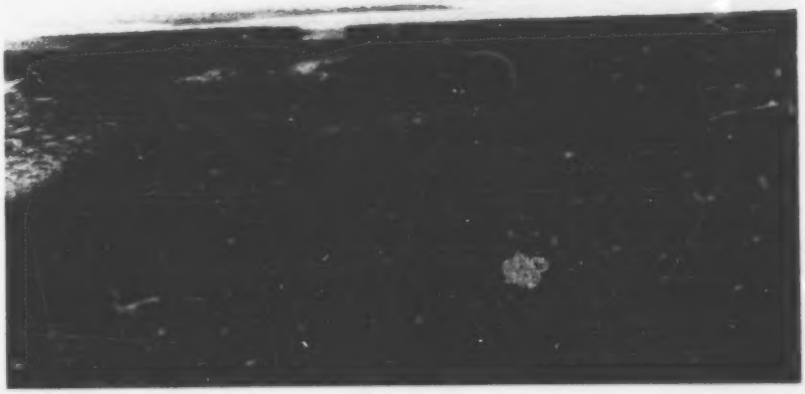
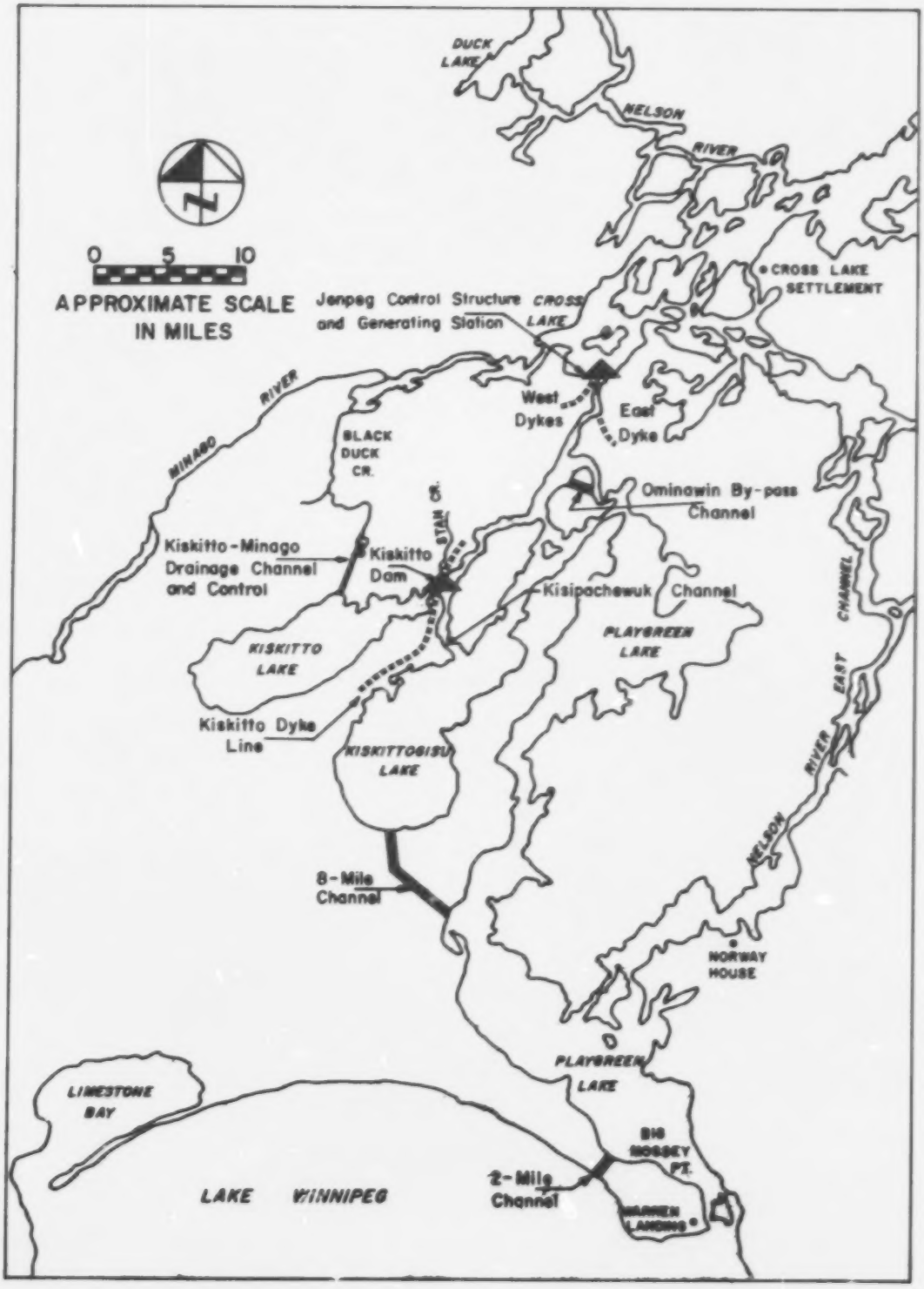


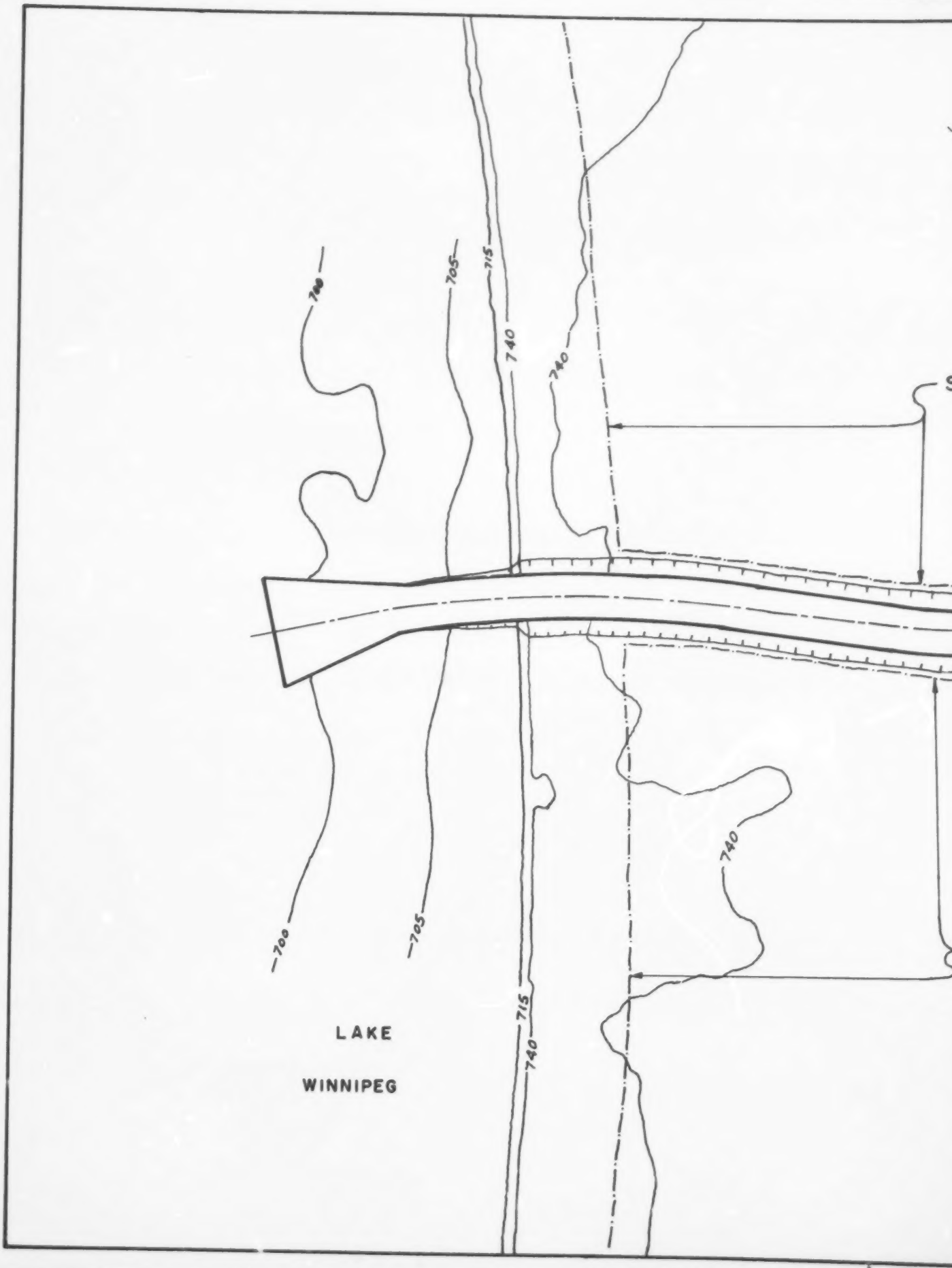
Photo 6

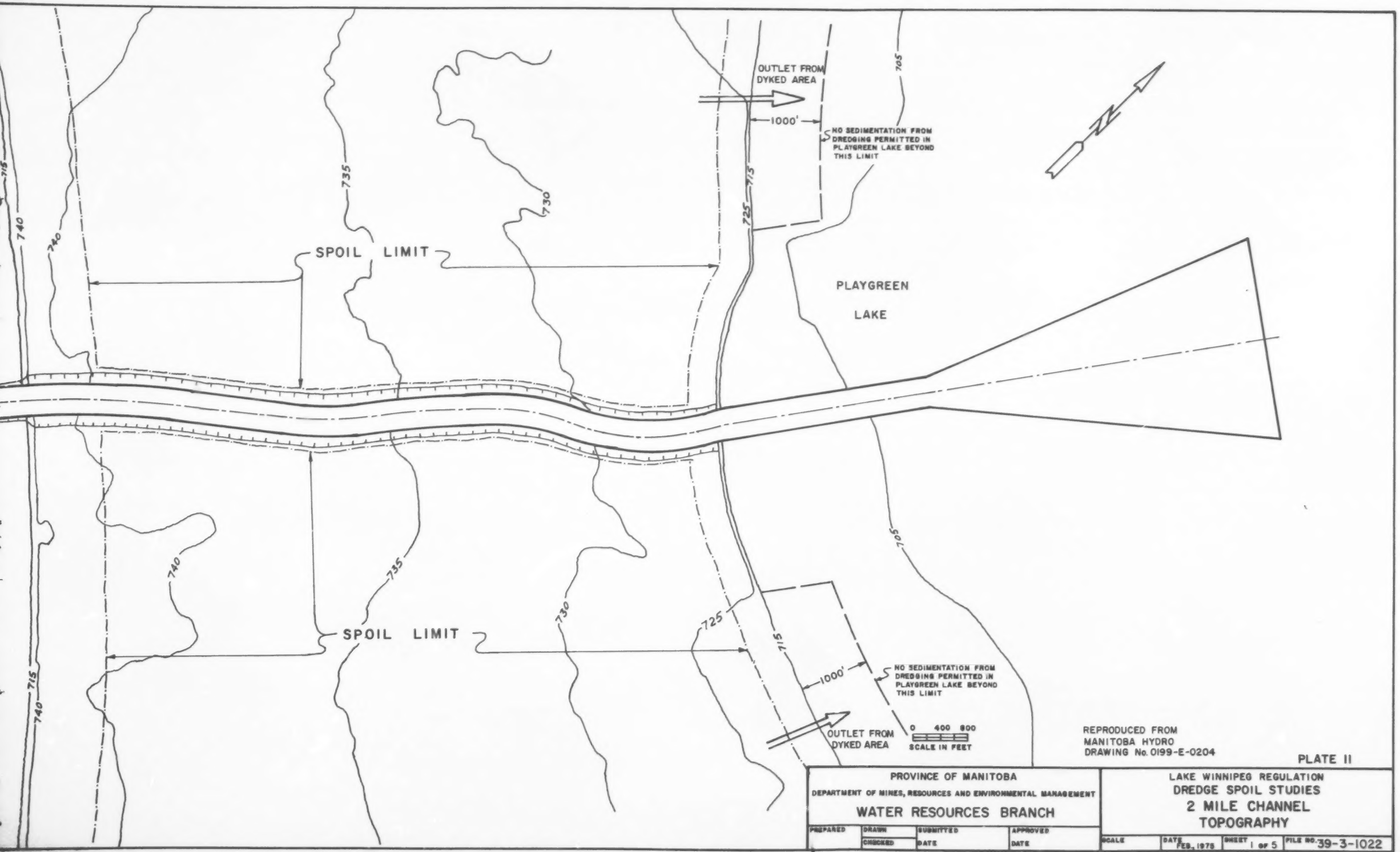
Route of 8-Mile Channel. Entrance to channel is at top of photo, Kiskittogisu River is in foreground.



LAKE WINNIPEG REGULATION

PLATE I


700
705
715
740
740
740
700
705
715
740
LAKE
WINNIPEG



REPRODUCED FROM
MANITOBA HYDRO
DRAWING No. 0199-E-0204

PLATE II

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

PREPARED	DRAWN	SUBMITTED	APPROVED
	CHECKED	DATE	DATE

LAKE WINNIPEG REGULATION
DREDGE SPOIL STUDIES
2 MILE CHANNEL
TOPOGRAPHY

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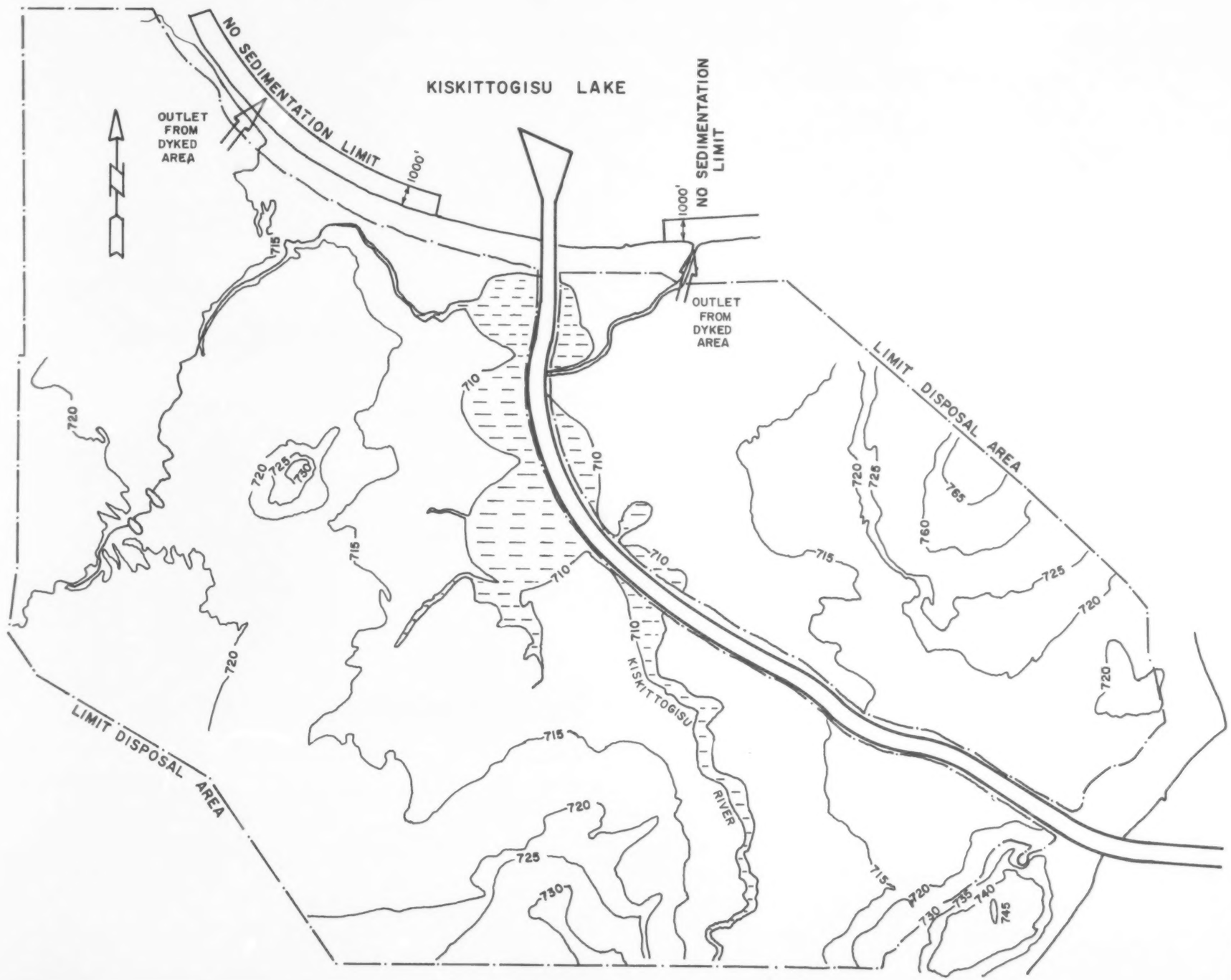

REPRODUCED FROM
MANITOBA HYDRO
DRAWING No. 0199-E-0203

PLAYGREEN

LAKE

0 5000
SCALE IN FEET

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEME
WATER RESOURCES BRANCH

PREPARED	DRAWN	SUBMITTED	APPROVED
	CHECKED	DATE	DATE

REPRODUCED FROM
MANITOBA HYDRO
DRAWING No. 0199-E-0203

PLAYGREEN

LAKE

0 5000

SCALE IN FEET

PLATE III

PROVINCE OF MANITOBA				LAKE WINNIPEG REGULATION			
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT				DREDGE SPOIL STUDIES			
WATER RESOURCES BRANCH				8 MILE CHANNEL			
				TOPOGRAPHY			
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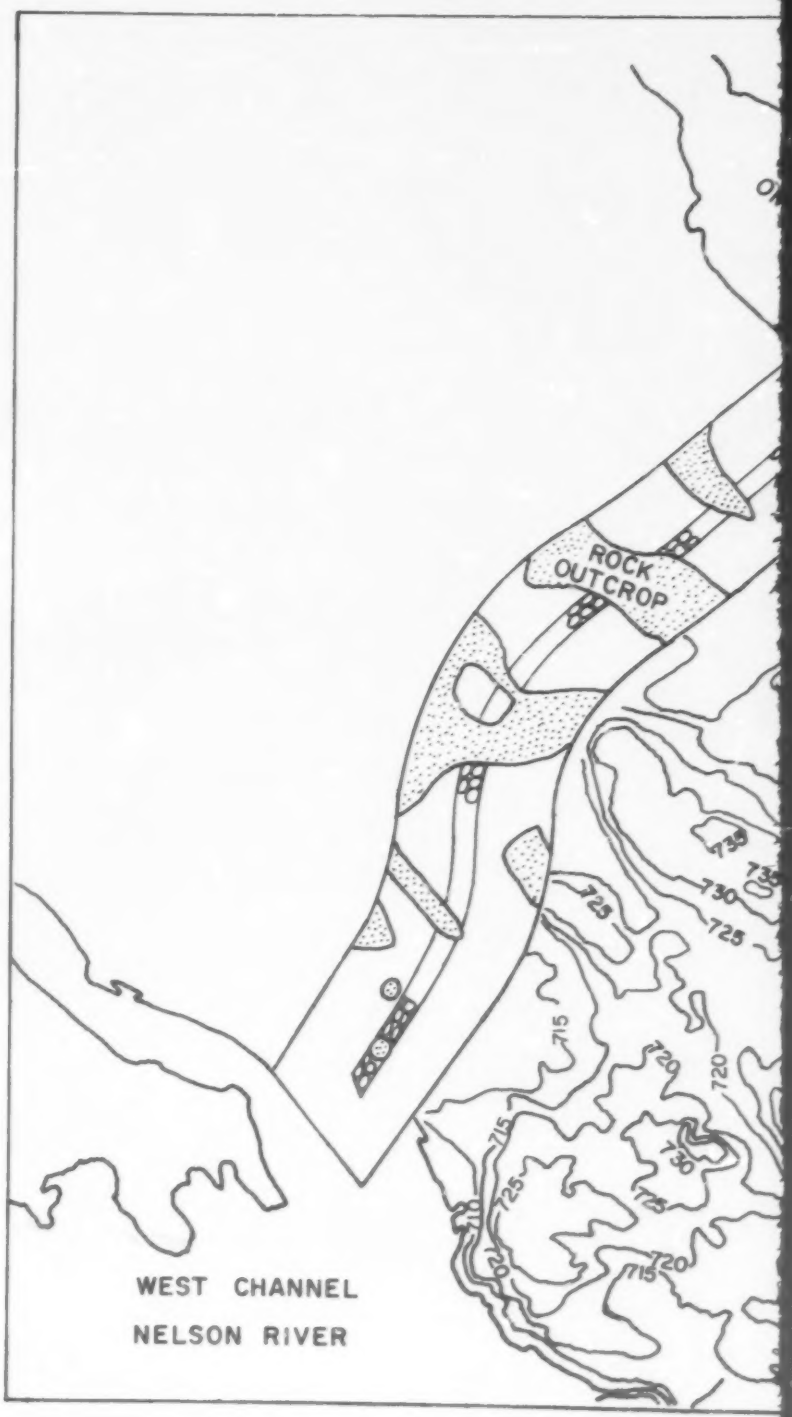
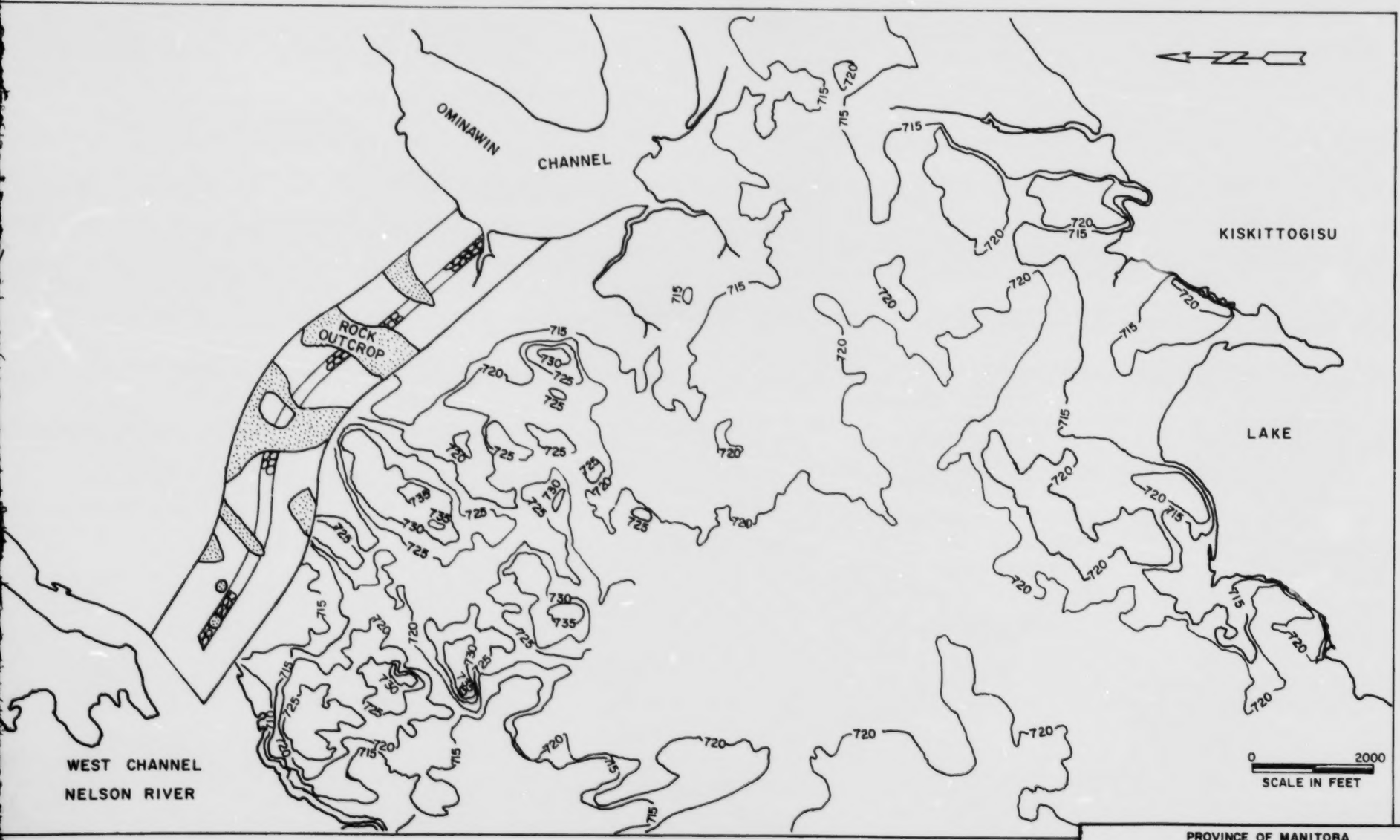
	CHECKED	DATE	DATE				


ROCK
OUTCROP
WEST CHANNEL
NELSON RIVER
715
720
725
730



REPRODUCED FROM
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DRAWING No. 0199-E-9301

PLATE IV

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

PREPARED	DRAWN	SUBMITTED	APPROVED
	CHECKED	DATE	DATE

LAKE WINNIPEG REGULATION
DREDGE SPOIL STUDIES
OMINAWIN BYPASS CHANNEL
TOPOGRAPHY

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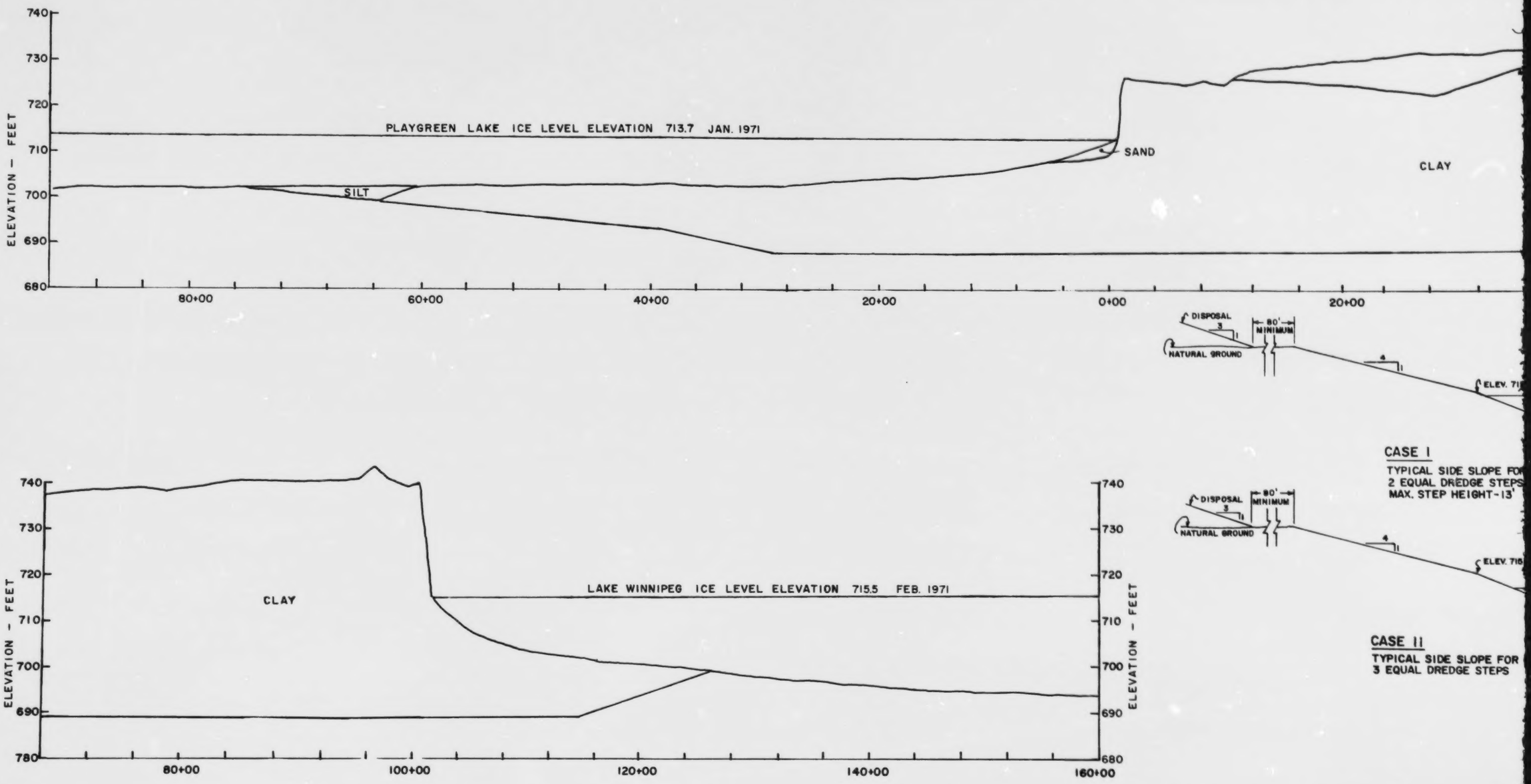
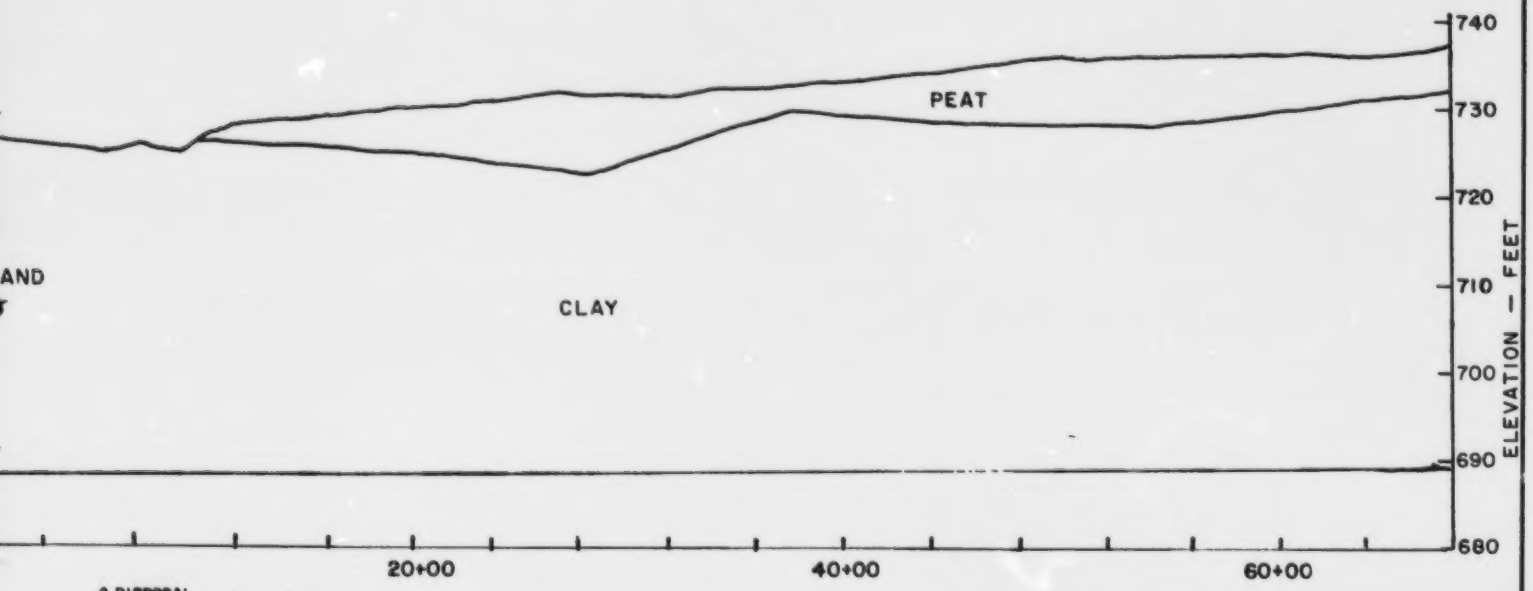
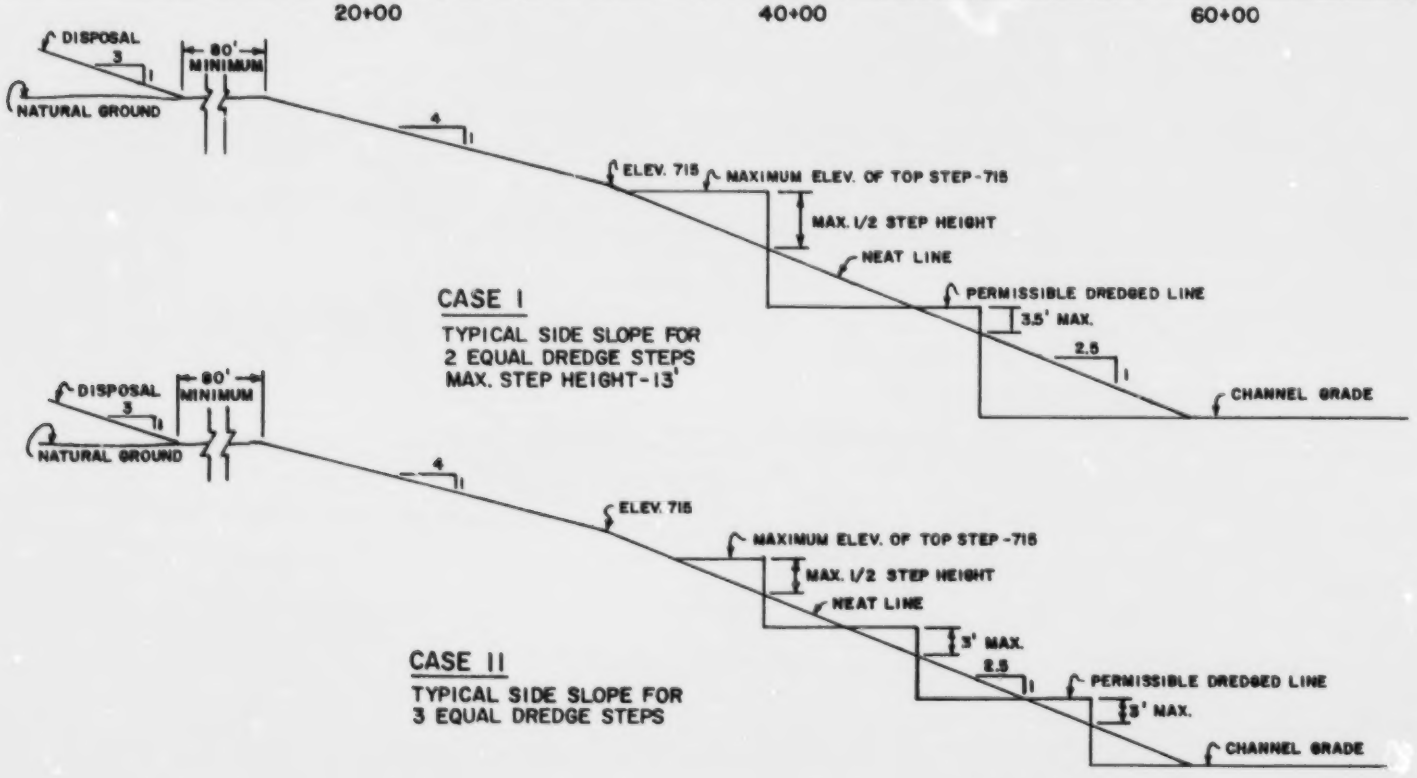

740
730
720
710
700
690
680
ELEVATION – FEET
PLAYGREEN LAKE ICE LEVEL ELEVATION 713.7 JAN. 1971
SILT
SAND
CLAY
80+00
60+00
40+00
20+00
0+00
20+00
DISPOSAL
3
1
80'
MINIMUM
NATURAL GROUND
4
1
ELEV. 71
CASE I
TYPICAL SIDE SLOPE FO
2 EQUAL DREDGE STEPS
MAX. STEP HEIGHT-13'
740
730
720
710
700
690
780
ELEVATION - FEET
CLAY
LAKE WINNIPEG ICE LEVEL ELEVATION 715.5 FEB. 1971
80+00
100+00
120+00
140+00
160+00
680
CASE II
TYPICAL SIDE SLOPE FOR
3 EQUAL DREDGE STEPS
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL
WATER RESOURCES BRAN
PREPARED
DRAWN
SUBMITTED
CHECKED
DATE
APPRO
DATE





CASE I

TYPICAL SIDE SLOPE FOR
2 EQUAL DREDGE STEPS
MAX. STEP HEIGHT-13'

CASE II

TYPICAL SIDE SLOPE FOR
3 EQUAL DREDGE STEPS

REPRODUCED FROM MANITOBA
HYDRO DRAWING #0199-E-0303

PLATE V

PROVINCE OF MANITOBA				LAKE WINNIPEG REGULATION			
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT				DREDGE SPOIL STUDIES			
WATER RESOURCES BRANCH				2 MILE CHANNEL			
				REFERENCE LINE PROFILE			
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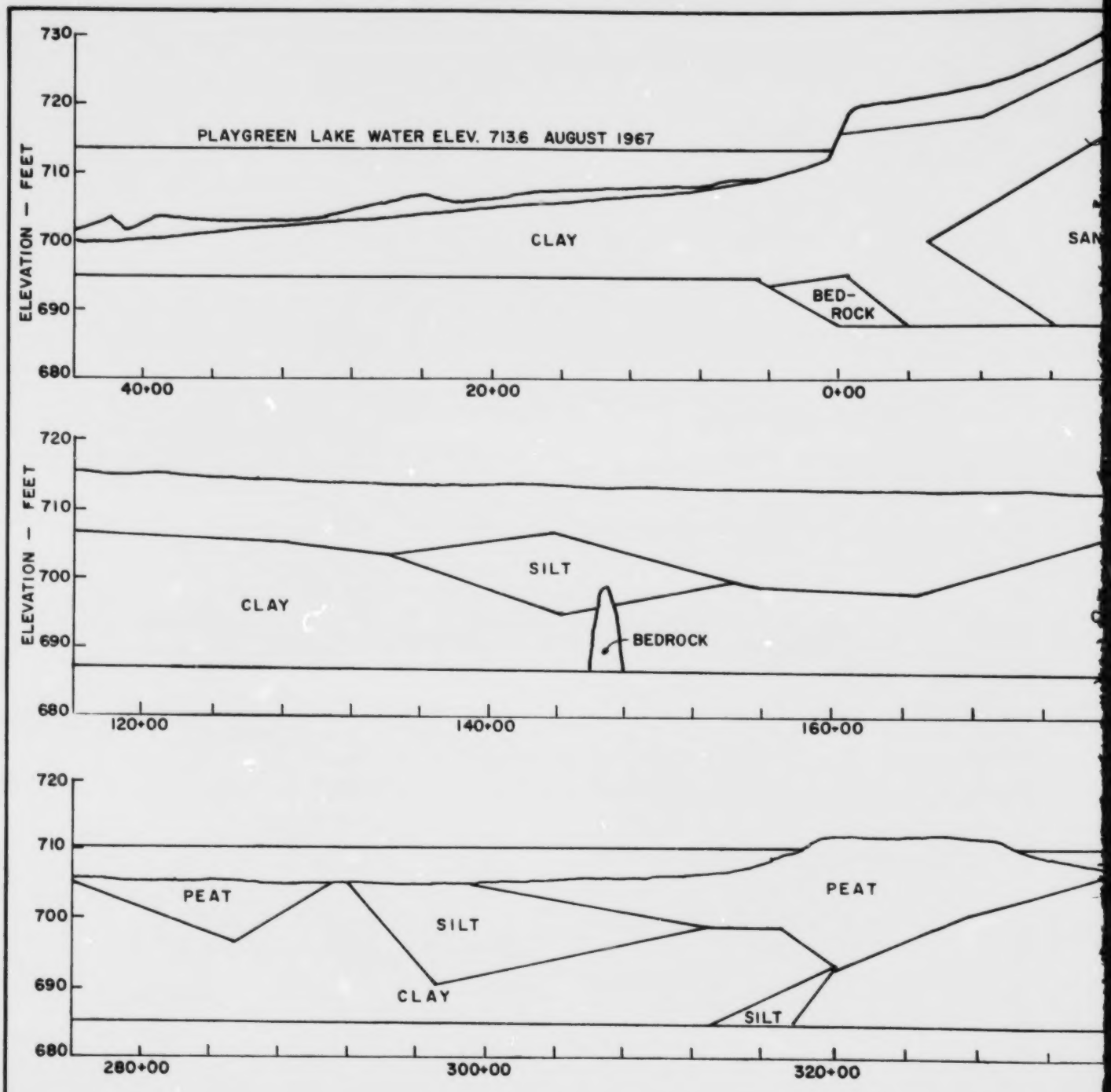
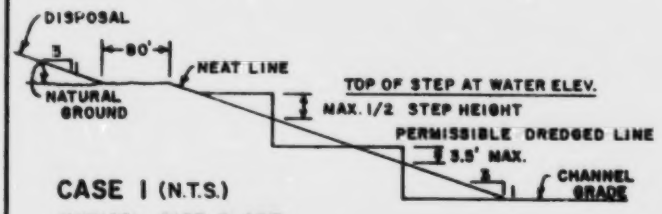
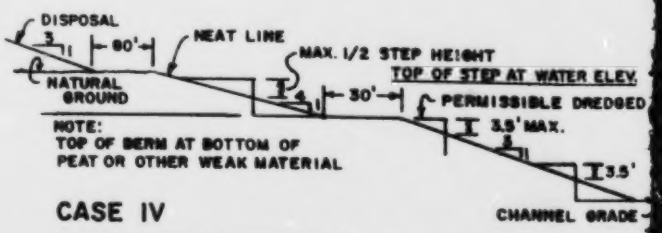




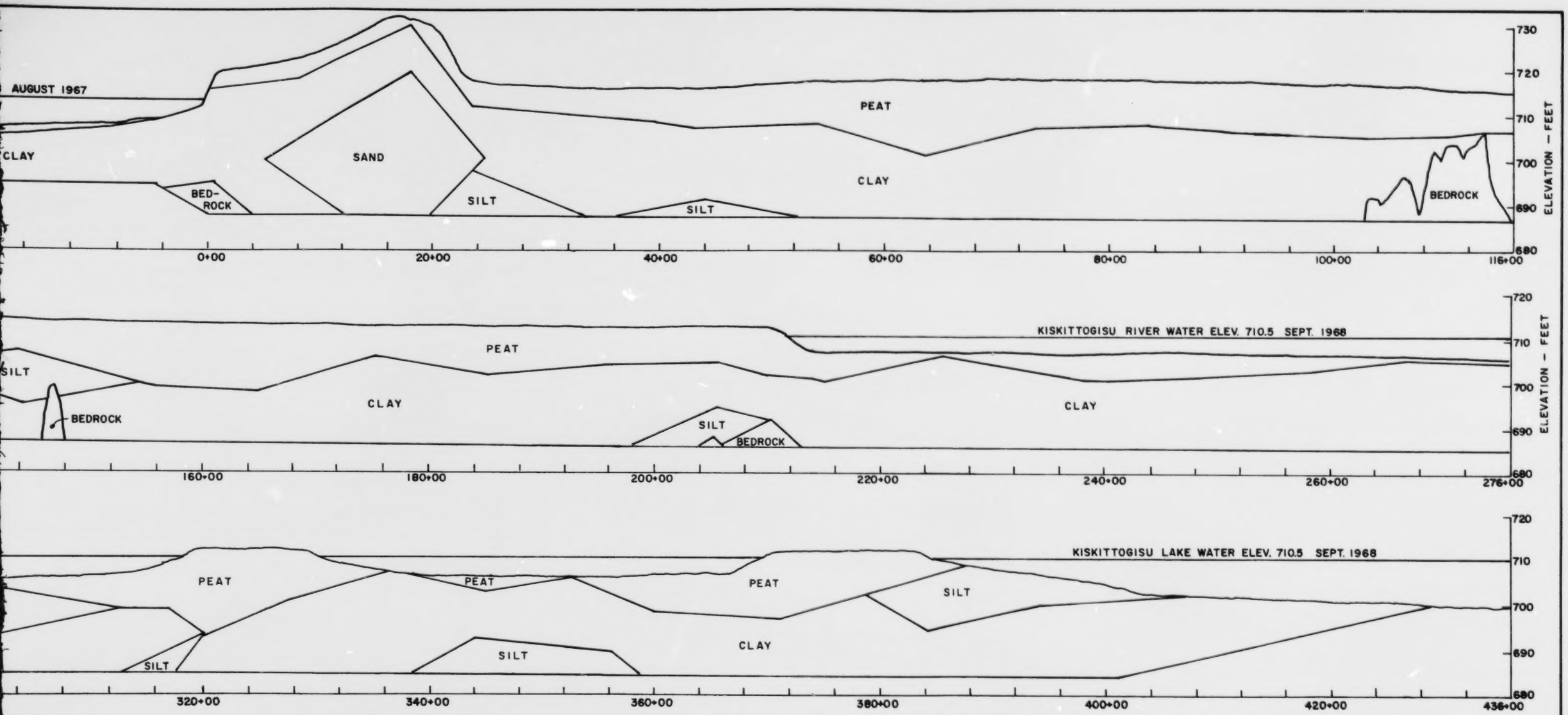
CASE I (N.T.S.)

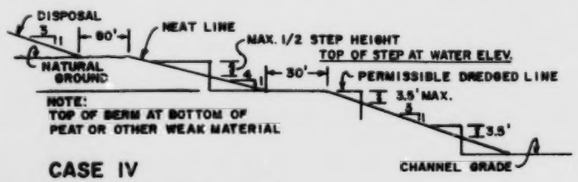
TYPICAL SIDE SLOPE
FOR 2 EQUAL DREDGE STEPS
MAX. STEP HEIGHT 13'



CASE IV

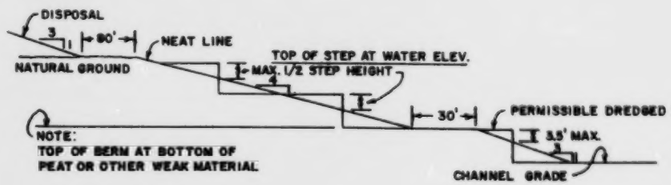
TYPICAL SIDE SLOPE FOR 2
EQUAL DREDGE STEPS BELOW
BERM. MAX. STEP HEIGHT 13'





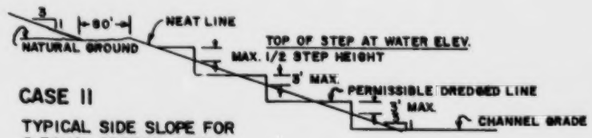
CASE IV

TYPICAL SIDE SLOPE FOR 2 EQUAL DREDGE STEPS BELOW BERM. MAX. STEP HEIGHT 13'



CASE III

TYPICAL SIDE SLOPE FOR 2 EQUAL DREDGE STEPS ABOVE BERM. MAX. STEP HEIGHT 13'



CASE II

TYPICAL SIDE SLOPE FOR 3 EQUAL DREDGE STEPS

REPRODUCED FROM MANITOBA HYDRO DRAWING #0199-E-0301

PLATE VI

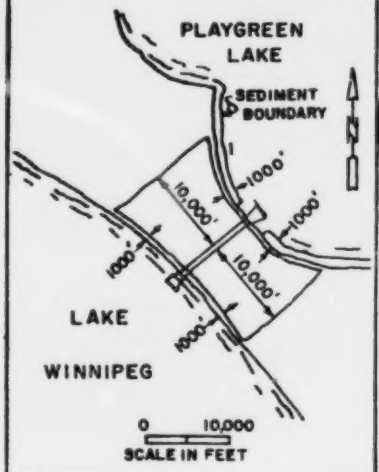
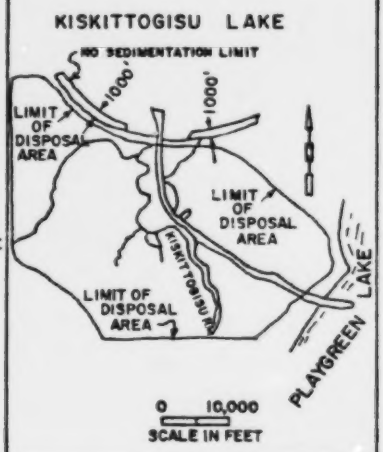
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

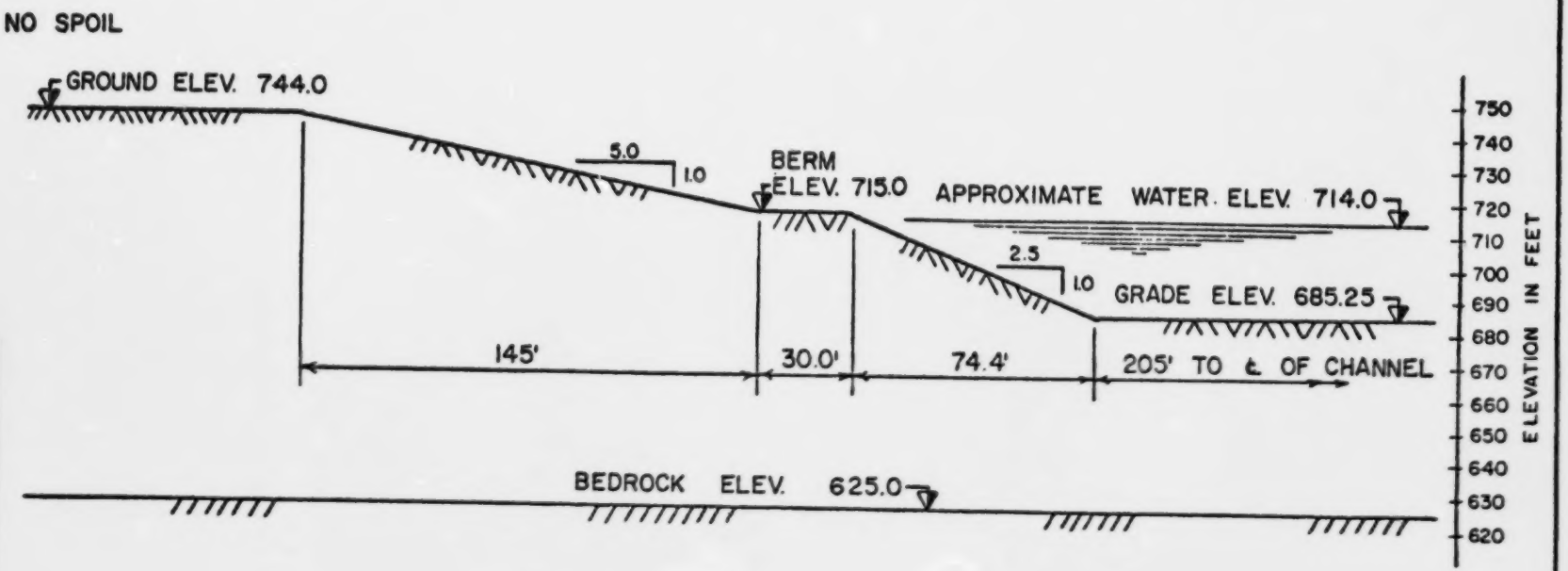
PREPARED	DRAWN	SUBMITTED	APPROVED
	CHECKED	DATE	DATE

LAKE WINNIPEG REGULATION
DREDGE SPOIL STUDIES
8 MILE CHANNEL
REFERENCE LINE PROFILE

SCALE	DATE	SHEET	FILE NO.
	FEB., 1975	5 of 5	39-3-1022

DREDGE-SPOIL DEPOSITS

	2-MILE CHANNEL	8-MILE CHANNEL	OMINAWIN BYPASS
DEPOSITION AREA (MAP)			
TYPE OF EXCAVATION	DREDGING	DREDGING	SCRAPER AND DRAGLINE
EXCAVATION MATERIALS	Clay 87% approx. Peat 12% approx. Others 1% approx. Clay is cohesive and generally of intermediate plasticity to high plasticity. Peat has high void ratios and unit weight of about 62.4 lb/ft .	Clay 58% approx. Peat 29% approx. Silt, Clay Silt & Sandy Clay 7% approx. Sand 4% approx. Bedrock 2% approx. Clay and peat are similar to clay and peat of 2-mile channel.	Clay Peat Rock The clay and peat are similar to that in the 2-mile channel and 8-mile channel.
EXCAVATION VOLUME	Unclassified 12,860,000 cu. yds.	Unclassified 22,100,000 cu. yds.	Unclassified 8,700,000 Rock 650,000 Total 9,350,000 cu. yds.
SPOIL DEPOSITION	Clay cuttings are highly dependent on dredge operation. Intact ("balled") cuttings which represent most of the clay spoil will settle almost instantly. Individual particles will settle very slowly. Individual particles of silt and sand will settle quickly. Some peat may float.		Because of conventional excavation, there are no problems involving soil particle settlement in water.
CONTROL MEASURES (SILTY-WATER)	Dykes to confine dredged material placed not within 500' of Playgreen Lake. Deposition of solids limited to within 1000' of effluent outlets and shore.	Dykes to confine dredged materials placed not within 2000' of Playgreen Lake and 1000' of Kiskittogisu Lake. Deposition of solids limited to within 1000' of shoreline in the area of the mouth of the Kiskittogisu River.	Spoil will be placed no nearer than 500' to any water body.



CROSS-SECTION OF 2-MILE
CHANNEL AT STA. 96+60

0' 10' 20' 30' 40' 50'

HORIZONTAL SCALE

SIDE SLOPE FOR DEEP CUT IN 2-MILE CHANNEL

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

PLATE VIII

APPENDIX 2 - VOL. 1 - D

REVIEW OF ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE CHANNEL

REVIEW OF ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION AT 8-MILE CHANNEL

by

V. GALAY and A. BARACOS
Department of Civil Engineering
University of Manitoba
Winnipeg, Manitoba
January, 1974

sub-contracted by:

Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

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PRESENT CONDITION OF DYKES	4
DEPOSITION WITHIN SPOIL AREAS	6
FUTURE CONDITION OF DYKES	7
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7	South dyke along Kiskittogisu River.
8	Varved clay from "clay balls".
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10	Dykes along south side.
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15	Fine spoil deposits have been washed into low areas on south side of channel.
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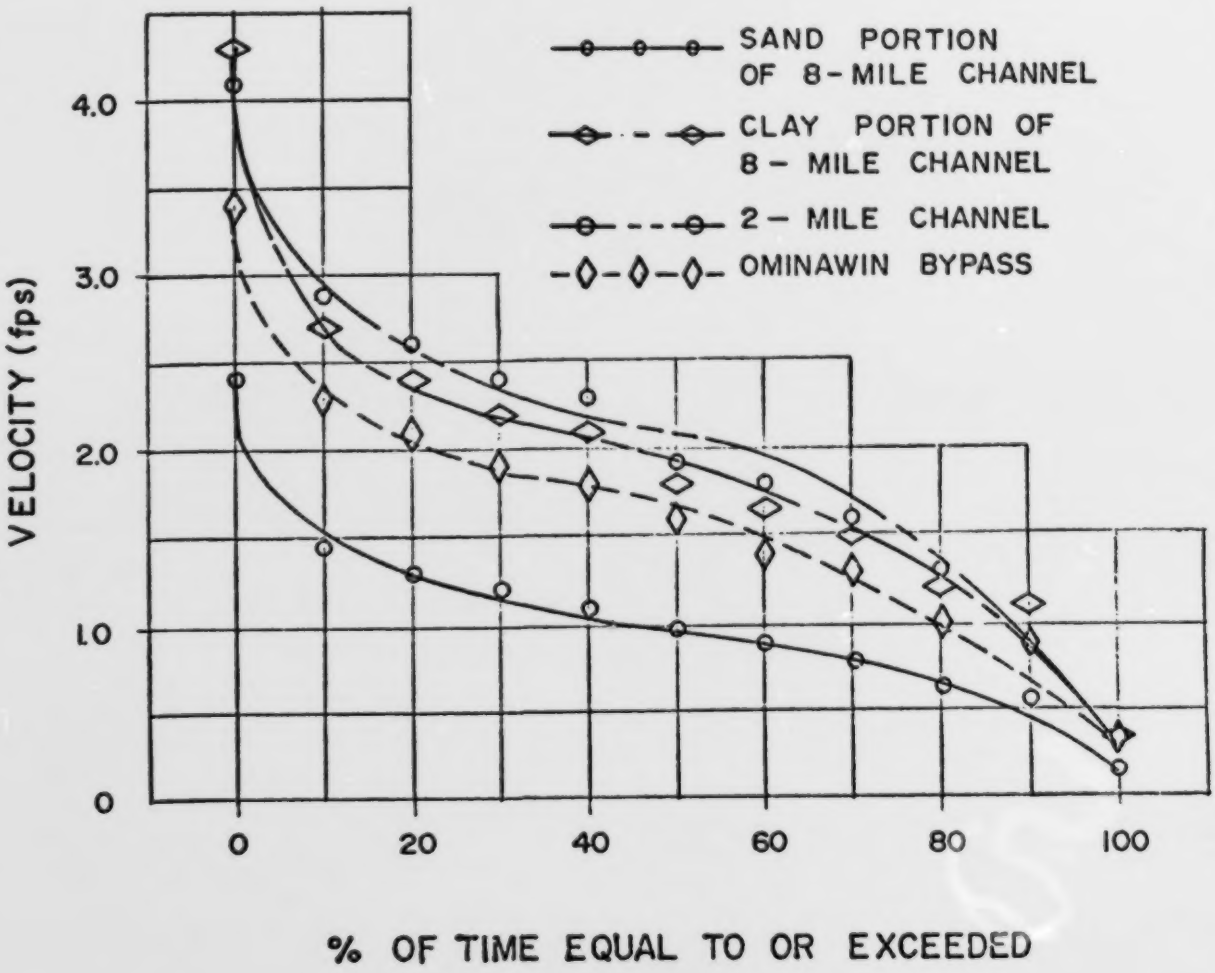
4	Probable Cross-Sections in Marsh Areas
5	Future Shorelines With Unconfined Channel (After Unies)



VELOCITY DURATION CURVES

PLATE IX

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

INTRODUCTION

This report is a follow-up to an earlier report entitled, "Lake Winnipeg Regulation Dredge Spoil Studies and Aspects of Channel Operation" dated July, 1972, which dealt primarily with the 2-mile and 8-mile channels. After completion of that report, it became apparent that the level of Kiskittogisu Lake will be at elevations 713 and 714 for a longer duration than originally anticipated. The writers were then requested to review the future performance of the dykes along the 8-mile channel and to assess the future location of the south shoreline of Kiskittogisu Lake.

This Review presents information on the status of dredging, the present condition of dykes and the duration of water levels on Kiskittogisu Lake. Comments on future dykes and shorelines are also presented.

DURATION CURVE FOR KISKITTOGISU LAKE LEVELS

Figure 1 shows duration curves for Kiskittogisu Lake levels on a mean monthly basis.

The lake elevations naturally fluctuate from 709 to 711, but after regulation the levels will be nearer 712 and 714. These higher lake levels will occur in the latter part of the summer when wind storms are more frequent.

STATUS OF DREDGING IN THE 8-MILE CHANNEL

The 8-mile channel was visited on August 27 and 28, 1973, by the writers and Mr. F. Penner, P. Eng. of the Water Resources Branch. Arrangements were made for inspection of the channel by truck along constructed dykes, by helicopter for the entire length and adjacent areas and by boat. In discussing with Mr. T. Bentham, Manitoba Hydro's Job Superintendent, it was determined that about 40% of the necessary dredging had been completed. There were two dredges in operation; a 36 inch dredge had been brought in to assist dredging at the inlet of the channel (see Photos 1 and 2, photo locations are shown in Figure 2). The dredged material consisted of sand, silt and peat and was deposited behind truck-dumped dykes into the spoil area (Photo 14 and 15). The sand generally deposits near the end of the delivery pipe while finer material and peat is washed into the trees adjacent to the dykes.

The larger dredge, a 42 inch one, had been working its way to the lower end of the channel (see Photos 3, 4 and 5). The material dredged in the lower reaches consisted of clay, silt and peat which was being used to construct containment dykes along the channel sides.

It was also observed that the impact of the dredge discharge could be used to displace soft underwater material and peat, resulting in a firmer base for the dykes. In fact, the discharge had such an impact on areas of peat that it disrupted the adjacent power line in the vicinity of the Kiskittogisu River (shown in Photos 3 and 13).

PRESENT CONDITION OF DYKES

The dykes formed by the deposition of dredged material were found to be flat, with very gradual side slopes (see Photos 3, 7, 11, and Figure 3). The predominant material within these dykes is clay in the form of "clay balls" (see Photos 5, 6 and 7). In the original report it was speculated that the cutter head would remove the clay in discrete lumps, "clay balls", which would not break up when passing through the pipeline. Photograph 8 shows that the natural layered structure of the clay has not been destroyed in the "clay balls" after dredging. The formation of "clay balls" results in an immediate deposition of the dredged clay and a minimum amount of suspended material making its way into the lower lakes. The dredge spoil dykes are relatively low. The "clay balls" have been deposited in water where bouyancy has further reduced the weight causing consolidation. There are void spaces between "clay balls". Under these conditions it is likely that the balls will soften as they expand to fill the voids. The dykes were too soft to support construction when examined, and little improvement, if any, can be predicted for the future.

The upper portion of the dykes are also subject to loss of strength from freezing and thawing. This tends to break the layered structure of the clay balls into friable nuggets which have only slight erosion resistance unless grass, reed, etc. cover can soon-enough develop a binding root system.

The dredge spoil dyke cross-sections shown in Figure 3 have been estimated on the basis of approximately balancing the amount of dredge excavation with the dyke volume to a known height. Actual under-water

surveys were not undertaken. However, this estimate does confirm that the dyke side slopes are very flat, for example in the order of 1' vertical to 75' horizontal. The flat slope is desirable from stability considerations and also minimizing erosion from wave uprush.

A long dyke has been constructed along the south side of the channel by dumping material from trucks (Photos 9, 10, 14 and Figure 4). The dyke has been well compacted by trucks and appears stable. At the west side of Kiskittogisu River, a narrow truck-dumped dyke has been washed out by wave action during storms and over-topping (Photos 11 and 12). The material in this dyke was, however, not highly cohesive, having sand and gravel mixed with silt and clay. Waves would not have difficulty in eroding this dyke.

A north dyke is presently being constructed along the channel (Photo 13) in order to trap dredging effluent that is deposited in this northern spoil area. The fill is being placed directly on the peat cover.

DEPOSITION WITHIN SPOIL AREAS

To date, most of the spoil deposits have been confined to the spoil area south of the channel. The deposited material has not spread out over the whole spoil area; it has been confined to the area near the channel (Photo 14). The finer material has seeped into the low lying areas which are sparsely covered with small spruce trees and shrubs (Photo 15). It is interesting to note that the dredge deposits are reasonably fertile. Grass has begun to grow on the spoil deposits (Photo 16). It would appear that the growth of various grasses or trees in the spoil areas will not be difficult in the future.

The amount of fine dredged material escaping into Kiskittogisu Lake is rather small. In fact, the lake is laden with suspended clay along the shoreline due to erosion of clay and peat banks by wave action (Photo 17). This erosion appears to produce concentrations of suspended material in the lake comparable to that introduced in the channel by dredging.

FUTURE CONDITION OF DYKES

As previously noted, the dykes along the 8-mile channel have been constructed in two ways: by dumping material from trucks and by dredge deposits.

The dredged spoil dykes along the lower part of the channel are low and likely undergoing softening before consolidation takes place. The south dredge spoil dyke will undergo some erosion by waves on the Kiskittogisu River. This wave attack would be minimized if the level of the local river could be kept below the crest of the dyke, but this does not appear possible because of low crest elevation. In fact, water will probably flow in both directions over these low dykes depending on the fluctuating levels on either side of the dyke. Erosion could be rapid where channels develop across the dyke.

If the dredge-spoil dykes along the lower channel are constructed with at least 3 feet of freeboard, then they should not experience any increase in rate of erosion because of the longer duration for high lake levels on Kiskittogisu Lake. The height of waves approaching the dykes is primarily dependent upon wind velocity and fetch, which do not change. Additional dredging will have to be carried out or alternatively winter-hauled material brought in, if this height of dyke is deemed necessary.

The truck-dumped dykes at the upper end of the channel in general have adequate freeboard. In addition, they have recieved considerable compaction from the trucks, and they are set back from the channel. A weak feature is their support on peat which is a highly compressible material. However, they have a roadway on top which can be used for servicing and repair as required.

FUTURE LOCATION OF SOUTH SHORELINE OF KISKITTOGISU LAKE

A recent study (Reference 1) of the future location for the south shoreline of Kiskittogisu Lake indicates that a substantial movement of the shoreline in a southern direction will take place (see Figure 5). With a longer duration of high lake levels, there is no doubt that a new shoreline will be developed; the exact future location is, however, difficult to assess precisely. With a southern movement of the shoreline, waves from the lake will attack the dredge-formed dykes more frequently and gradually erode them, probably at the same rate as the movement of the south shoreline. This process will probably result in a partial filling of the outlet transition of the channel into the lake.

It is recommended, that the southward movement of the shoreline be prevented by the construction of dykes parallel to the lake shore and carried until higher ground elevations are reached (see Figure 5). These dykes will have to be rip-rapped in order to prevent eventual destruction by lake waves. The existence of these dykes will result in a shift of the present sand beach (Photo 18) to a higher elevation adjacent to the dykes. Also, the stable dykes along this shoreline should prevent the erosion of the channel dykes at the lower end. The channel dykes will then have to withstand wave action only from waves that are generated in the channel or in Kiskittogisu River to the south.

Preservation of the shoreline or Kiskittogisu Lake, and the dredge spoil dykes along the lower part of the channel would confine a large area of floating peat. This peat if not confined can form floating islands as shown in Photograph 19.

REFERENCES

1. Unies Ltd. - "Physical Impact of Dredging and Lake Winnipeg Control Operation on Wildlife Habitat in the Vicinity of the Eight Mile Channel". Report to Canadian Wildlife Service, March, 1973.

PROVINCE OF MANITOBA
V. J. GALAY
REGISTERED ENGINEER

Submitted by:

V. Galay, P. Eng.

A. Baracos, P. Eng.

PHOTOGRAPH 1 - Status of dredging at entrance to 8-mile channel (August 27, 1973).

PHOTOGRAPH 2 - 36 in. dredge in operation. Dredge is removing peat and sand at entrance to 8-mile channel.

PHOTOGRAPH 3 - Status of dreding at lower end of 8-mile channel (August 27, 1973). The 42 in. dredge is operating in the background. Note the black peat deposits on the land side of the dyke (north side of channel).

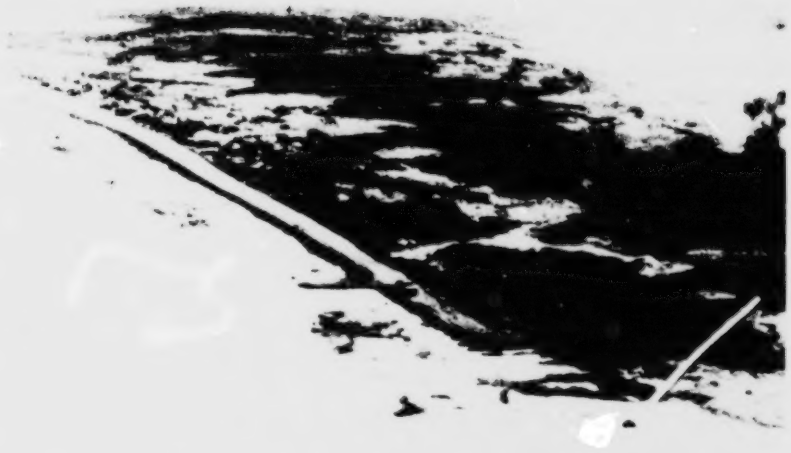
PHOTOGRAPH 4 - 42 in. dredge near the end of the 8-mile channel.

PHOTOGRAPH 5 - Operation of 42 in. dredge shows deposition of "clay balls" near the end of delivery pipe. Finer material and peat are jetted away from pipe.

PHOTOGRAPH 6 - "Clay balls" vary from about 4 in. in diameter. The deposit of "balls" is not sufficiently firm to support construction equipment.

PHOTOGRAPH 7 - South dyke along Kiskittogisu River. The dyke is rather flat and shows a predominance of clay balls. Over-topping at low spot will likely lead to erosion channels across dyke.

PHOTOGRAPH 8 - Varved clay from "clay balls". Cohesive structure of clay within "balls" has not been destroyed by dredging.

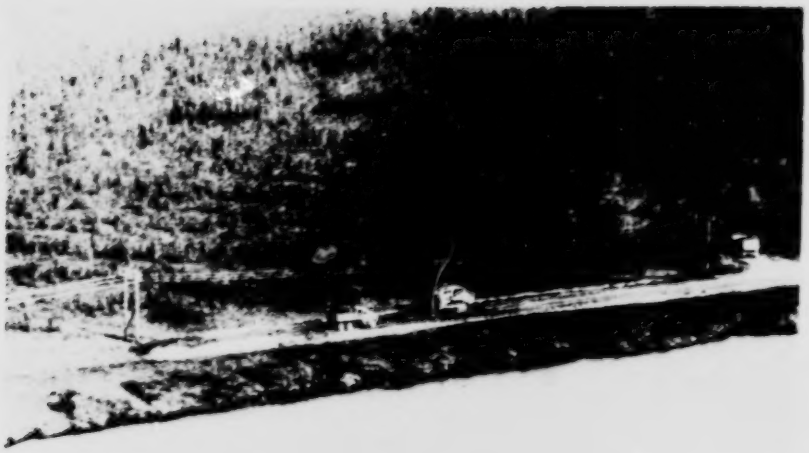


PHOTOGRAPH 9 - Dyke along south side constructed by dumping from trucks. Dredge deposition takes place behind dyke.

PHOTOGRAPH 10 - Dykes along south side. Lower dyke formed by truck dumping, upper dyke formed by dragline moving dredged "clay balls".

PHOTOGRAPH 11 - Remains of truck dumped dyke along west side of Kiskittogisu River.

PHOTOGRAPH 12 - Narrow dyke constructed during winter along west side of Kiskittogisu River destroyed by wave action. Dyke material consists of clay, silt, sand and gravel.



PHOTOGRAPH 13 - Construction of dyke by truck dumping along north side of channel.

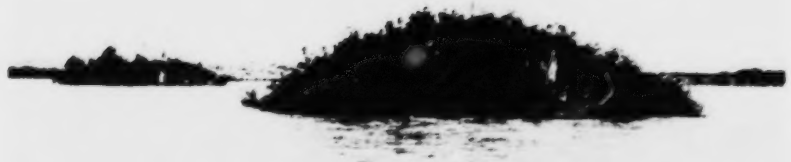
PHOTOGRAPH 14 - Spoil deposits along south side of channel. Sand and "clay balls" have deposited near end of pipe.

PHOTOGRAPH 15 - Fine spoil deposits have been washed into low areas on south side of channel.

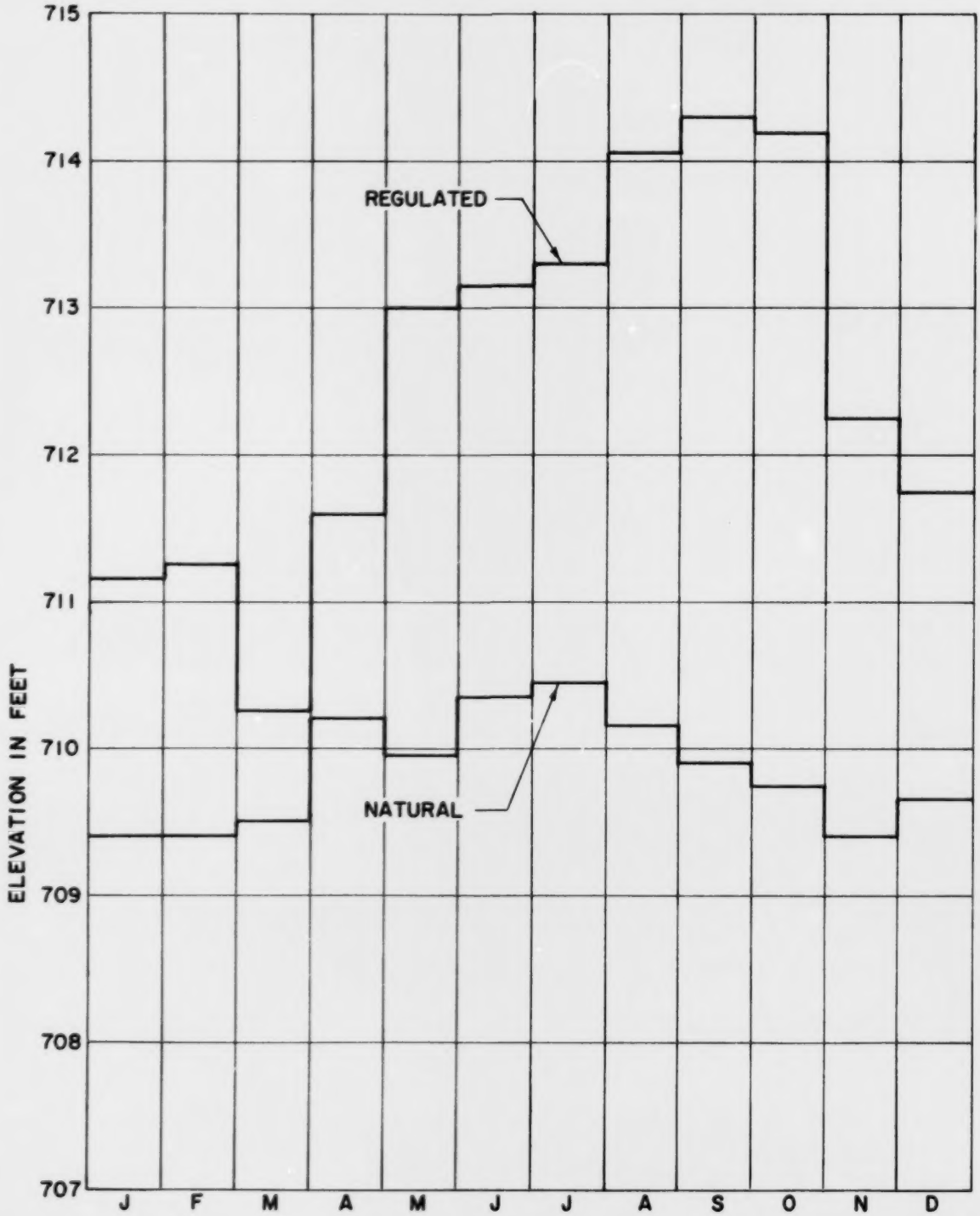
PHOTOGRAPH 16 - Vegetation growing on spoil deposit. The deposited material consists of silt, clay and peat.

PHOTOGRAPH 17 - Eroding east shoreline of Kiskittogisu Lake. The erosion has been carrying on for years. Note the grey colour of water indicating a high concentration of clay.

PHOTOGRAPH 18 - South shoreline of Kiskittogisu Lake. Deposition of sand has taken place along this shoreline.



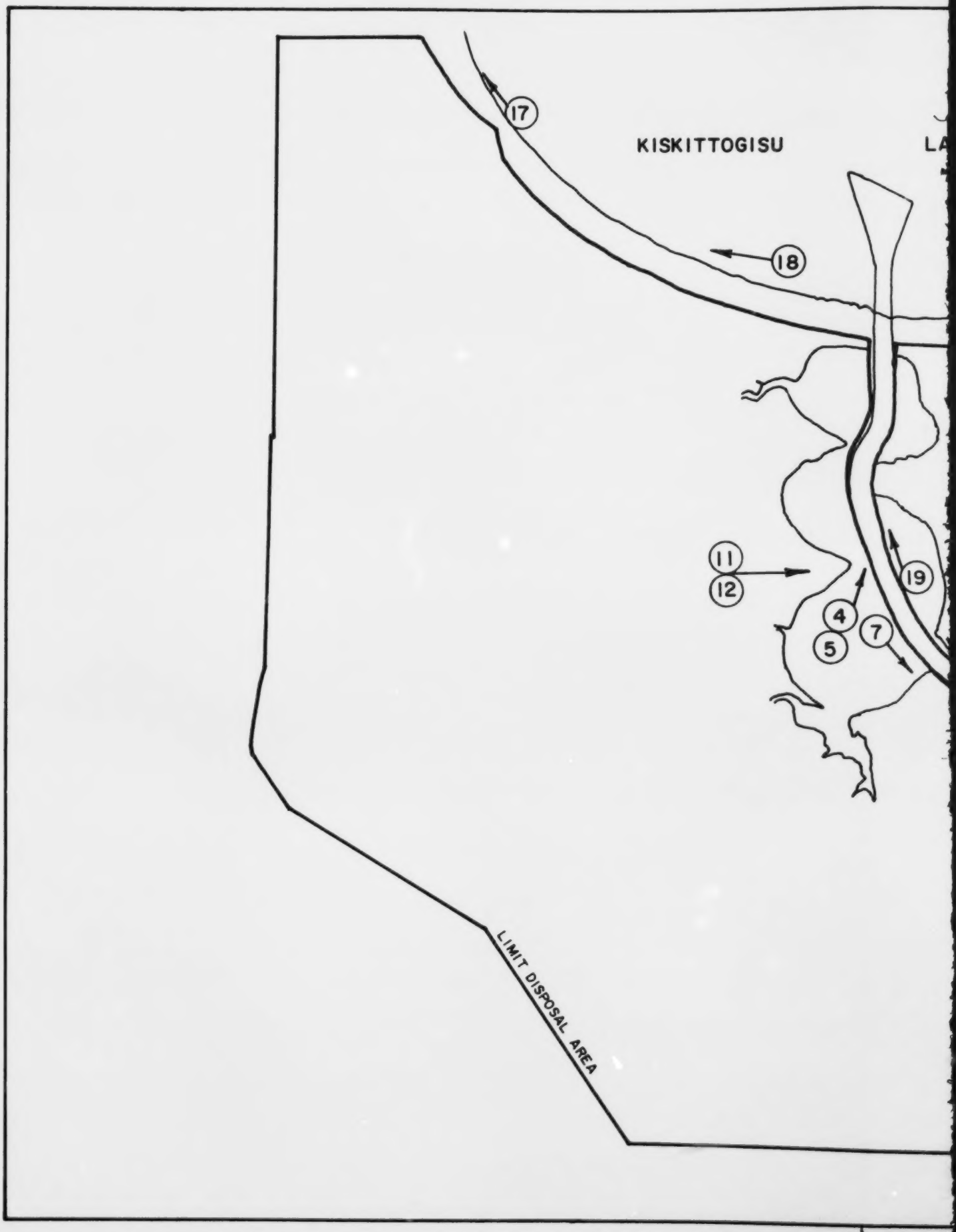
PHOTOGRAPH 19 - Floating peat islands at lower end of 8-mile channel.



LEVEL EXCEEDED 50% OF THE TIME
(FROM UNIES, REF. 1)

FIGURE 1

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA – MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD REVIEW OF 8 MILE CHANNEL MEAN MONTHLY WATER LEVELS KISKITTOGISU LAKE–REGULATED AND NATURAL
PREPARED DRAWN V.K. CHECKED SUBMITTED DATE 28-4-74 DATE	SCALE AS SHOWN DATE SHEET 1 OF 5 FILE NO. 51-2-1147


17
KISKITTOGISU
18
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12
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4
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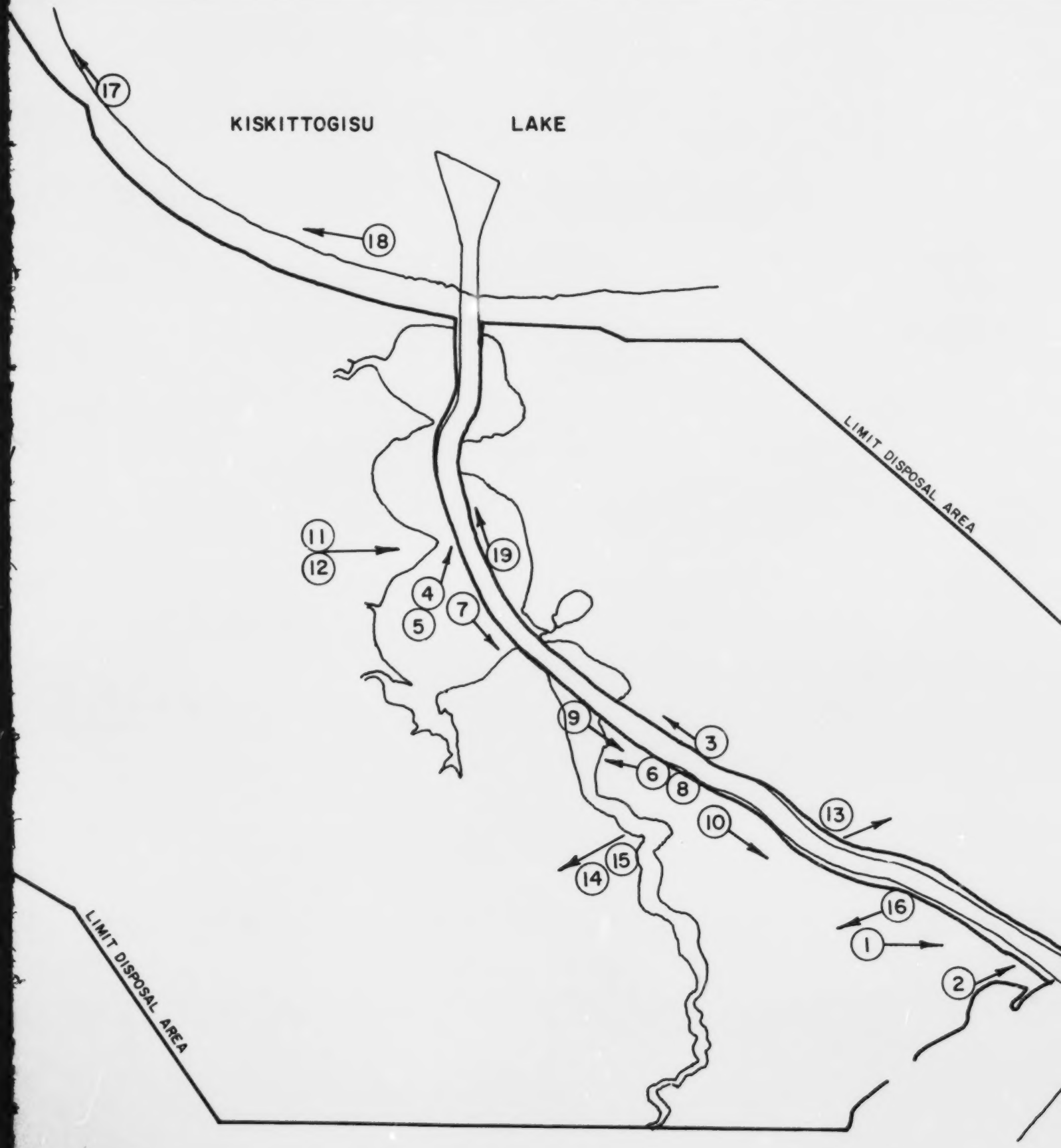
7
LIMIT DISPOSAL AREA


KISKITTOGISU LAKE
LIMIT DISPOSAL AREA
LIMIT DISPOSAL AREA
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2

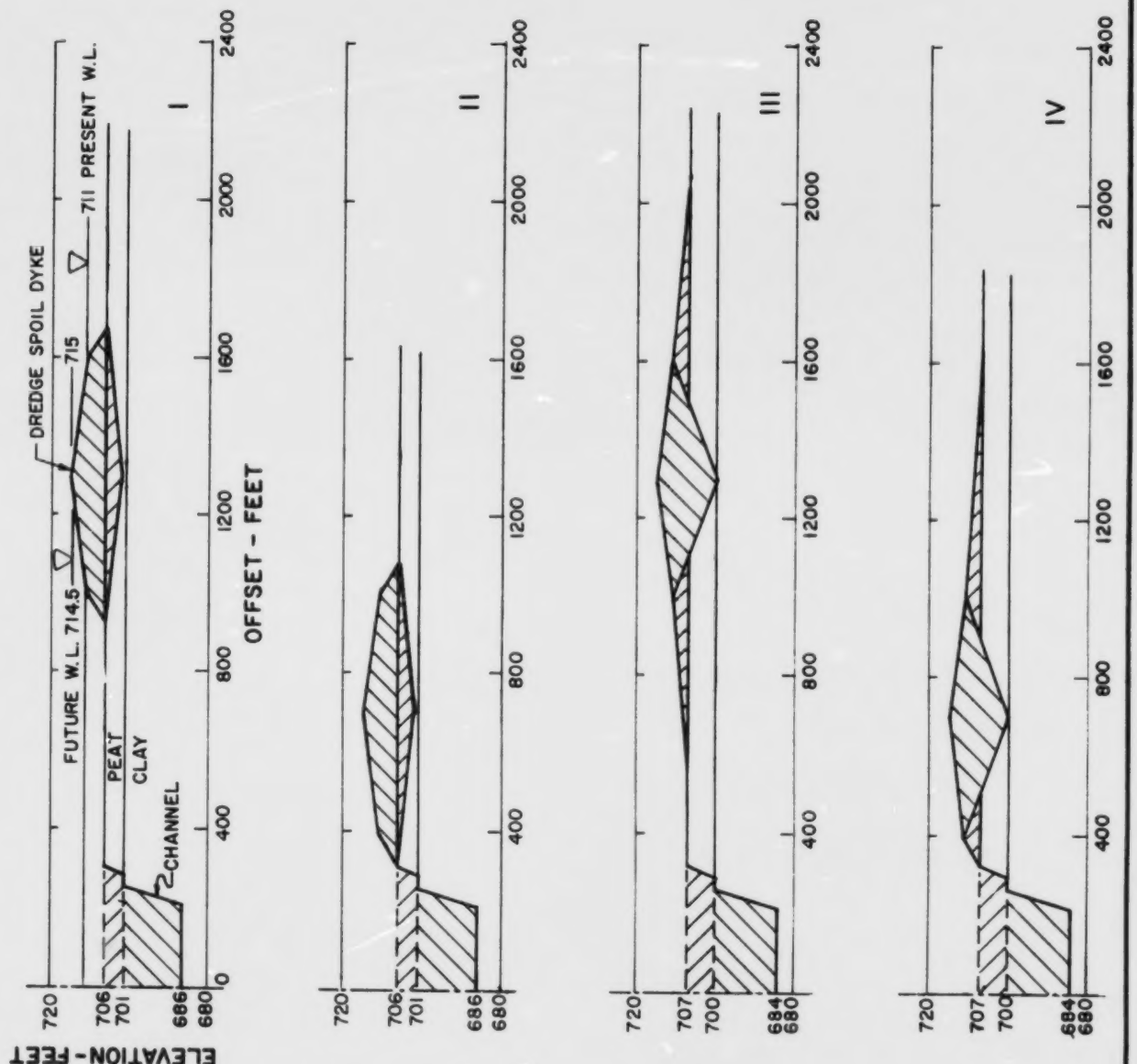
PLAYGREEN

LAKE

0 5000
SCALE IN FEET

FIGURE 2

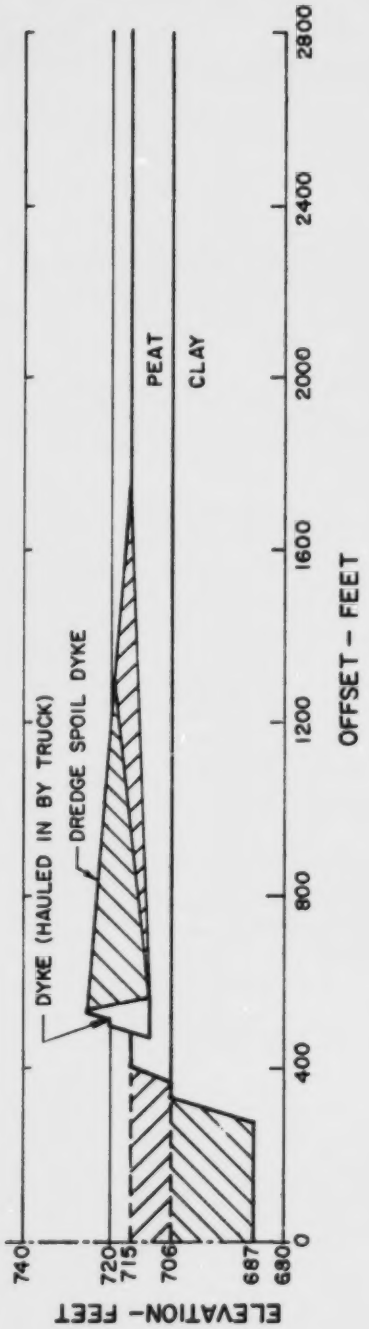
PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA – MANITOBA LAKE WINNIPEG, CHURCHILL, AND NELSON RIVERS STUDY BOARD REVIEW OF 8 MILE CHANNEL PHOTOGRAPH LOCATIONS
PREPARED: DRAWN V. K. / CHECKED; SUBMITTED; APPROVED; DATE 28-1-74	SCALE AS SHOWN; DATE; SHEET 2 of 5; FILE NO. 51-2-1147



(ESTIMATED FROM DREDGE AND FILL DATA).

FIGURE 3

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA — MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD REVIEW OF 8 MILE CHANNEL DREDGE-SPOIL DYKES SHOWING VARYING OFFSET DISTANCES FROM CHANNEL
PREPARED — DRAWN V. K. — CHECKED — SUBMITTED — DATE 28-1-74 — APPROVED — DATE	SCALE AS SHOWN — DATE — SHEET 3 OF 5 — FILE NO. 51-2-1147



DREDGE SPOIL PUMPED BEHIND TRUCK DUMPED DYKE. (ESTIMATED FROM DREDGE AND FILL DATA).

FIGURE 4

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA – MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD REVIEW OF 8 MILE CHANNEL PROBABLE CROSS-SECTIONS IN MARSH AREAS
PREPARED V. K. SHEEKEY DATE 28-1-74	SCALE AS SHOWN DATE SHEET 4 OF 5 FILE NO. 51-2-1147

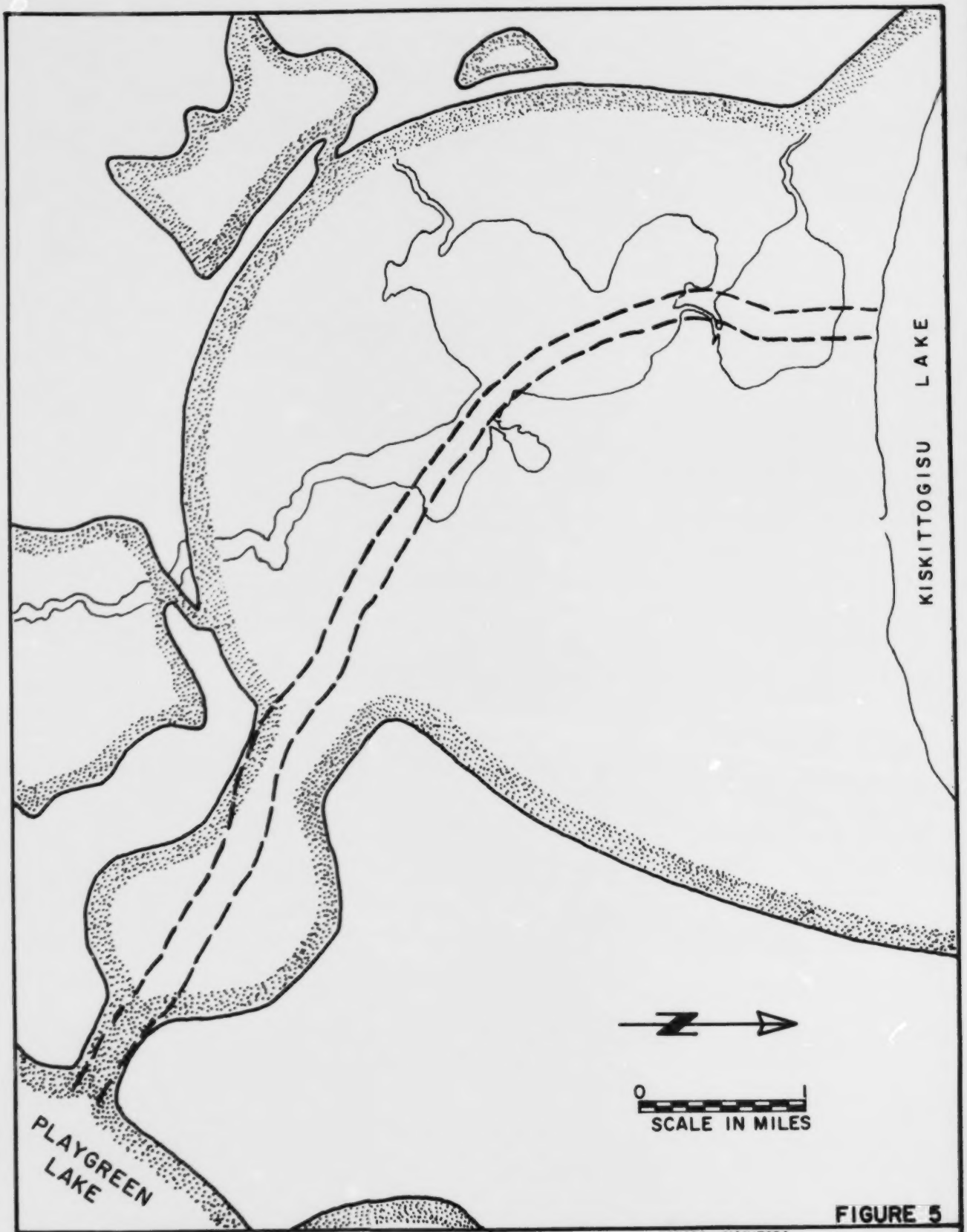


FIGURE 5

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA – MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

REVIEW OF 8 MILE CHANNEL
FUTURE SHORELINES WITH
UNCONFINED CHANNEL (AFTER UNIES)

PREPARED	DRAWN V.K.	SUBMITTED	SCALE AS SHOWN	DATE	SHEET 5 OF 5	FILE NO. 51-2-1147
	CHECKED	DATE 28-1-74				

APPENDIX 2 - VOL. 1 - E

ASPECTS OF CHANNEL CONSTRUCTION AND OPERATION FOR THE SOUTH BAY - ISSETT LAKE DIVERSION CHANNEL

ASPECTS OF
CHANNEL CONSTRUCTION AND OPERATION
FOR THE SOUTH BAY - ISSETT LAKE DIVERSION CHANNEL

by

A. BARACOS and V. GALAY
Department of Civil Engineering
University of Manitoba
Winnipeg, Manitoba
March, 1974

sub-contracted by:

Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

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Abstract

The proposed channel from Southern Indian Lake to Issett Lake is described. Based on our examination of construction contract documents and a visit to the site during the summer of 1973, predictions are made of the impact of the construction and operation of the channel on the local environment.

The channel will be confined in a saddle area between adjoining high ground. It will follow a route connecting several existing bodies of water. The slope of the channel bed will be controlled by numerous bedrock outcrops. Rock excavation will be required along much of the channel route.

Some sliding of the channel slopes may occur in areas where permafrost exists in clays and silts to depths of up to 56 feet. The tendency for the channel to shift where sliding or erosion takes place is also limited by bedrock outcrops. Re-design of some cross-sections of the channel will be necessary as excavation exposes bedrock irregularities, unexpected soft ground or very unstable conditions.

Because of conventional excavation instead of dredging, the effects of the disposal of excavation materials will be limited. These materials can be advantageously placed in low areas limiting the extent of inundation and the effects of inundation.

The excavation offers an important and unique opportunity to study in-situ permafrost conditions, and excavation procedures. The undertaking of such a study would be most valuable for future northern works.

SOUTH BAY TO ISSETT LAKE CHANNEL

PHYSICAL IMPACT STUDY

Terms of Reference

A key project in the planned diversion by Manitoba Hydro of water from the Churchill into the Nelson River by way of the Rat and Burntwood Rivers, is the construction of the Channel from South Bay on Southern Indian Lake to Issett Lake. The study of this project was undertaken with the following objectives stated in the terms of reference:

A. To describe the nature and extent of the proposed channel, its construction and operation. The description was to be in a form that would be of benefit to other study groups taking part in the activities of the Lake Winnipeg, Churchill and Nelson Rivers Study Board.

B. To examine hydraulic and soils information in relation to possible erosion, sedimentation, wave action and inundation effects, as well as side slope stability especially in permafrost excavations.

The basis for this study was to be an examination of the Manitoba Hydro contract and related documents, as well as a visit to the site undertaken during August of 1973. Acknowledgement is made to Manitoba Hydro for arrangements to visit the project, and particularly to Mr. Richard Zingle, project engineer for interviews at the site.

General Information

Figure 1 shows the general location of the study area. Figure 3 shows the location of the channel with respect to Southern Indian Lake and Issett Lake. Photographs 1 and 2, show the route of the proposed channel. It will be noted that a considerable portion of the approximate

5.6 mile length of the channel passes through existing bodies of water. Downstream from South Bay, the first mile is actually an existing arm of South Bay.

At the end of the South Bay arm is found a natural rock dyke, only a few hundred feet wide separating the watershed of the Churchill and Nelson Rivers. Lack of soil cover on this dyke, and its present relatively low free board (at times as little as 5 feet) above Southern Indian Lake, suggest that in the past there has been flow over the dyke. Below the dyke are in turn, Thin Lake, Grassy Lake and finally Issett Lake, all interconnected by small streams.

The proposed project involves excavation of a well-defined channel, followed by removal of the natural dyke. Flow through the channel will result from the raising of Southern Indian Lake to elevation 847 (possibly at a later date to elevation 850 if required), and control from a structure to be constructed at Notigi, downstream from Issett Lake.

The minimum bottom width of the channel will be 200 feet, and range up to 520 feet at the discharge end into Issett Lake. The top width is 1060 feet as defined by the edge of disposal areas for excavated soil adjacent to either side of the channel. Generally low adjoining areas have been designated for the disposal of excavated materials. Excavation depths range up to 40 feet. Clearing of trees and brush preceeded the 1973 summer season. As is shown in Photographs 1,2,4,7 and 8, this operation has left the site in a clean and neat condition.

Work during the summer of 1973 included the establishment of construction camps and access roads. The contract for actual channel excavation was awarded during November 1973. The contractor successfully

bidding for the project has elected to use conventional rock and earth excavation procedures instead of dredging.

The date of removal of the rock dyke (final blasting) has been scheduled for the end of October 1975. Controlled flow through the South Bay Channel could commence some months earlier, possibly as early as July 1975, with partial removal of the rock dyke.

Topography and Geotechnical Considerations

The proposed channel follows a saddle area between generally well-defined higher ground on either side underlain by bedrock. Precambrian bedrock outcrops in a number of locations where it appears scoured free of covering materials. Photographs 2, 3, 4 and 7 show such outcrops. The bedrock surface elevation is highly variable. Figures 8 and 9 show how the bedrock elevation not only varies along the length of the channel, but also across the width. Excavation of the bedrock will require drilling and blasting.

Overlying the bedrock are extremely varied soil conditions. A large portion of the soil to be excavated consists of high plasticity (CH) and intermediate plasticity (CI) clays. Photograph 5 taken in a borrow area, shows the layered or varved structure found in the clays associated with glacial lake deposits. Because of similar geological origin, it can be anticipated that the clays will be similar in properties to those found in Thompson and at South Indian Lake. The properties of these materials are described in previous reports (References 1 and 2).

The silts (ML), silty clay (CL), sands and gravels shown on Figures 8 and 9 appear to be glacial and glacio-fluvial deposits, pre-

dating or possibly in some cases concurrently deposited with the clays. Thus the glacial and glacio-fluvial materials will likely to be found below the clays, but in some cases as erratic pockets with clay on the top and sides.

The results of the test hole program show some unusually great depths of permafrost in comparison to what has been found in other locations such as Thompson. Several holes show permafrost to a depth of at least 40 feet. In the vicinity of Grassy Lake, depths of 56 and 72 feet of permafrost were found. Ice segregation in the form of thick layers was found between the 50 and 55 foot depths in the hole showing the 56 feet of permafrost.

Thick ice layers were also seen in the permafrost exposed by sliding along the edge of Grassy Lake and other small bodies of water. These were associated with sliding as shown in Photographs 8 and 10. Some of the permafrost appears to be covered with a relatively thick layer of peat. However, not all permafrost appears to be so covered, and in some cases there is no permafrost under peat. Generally it can be said that permafrost occurrence is highly erratic, and in some areas very substantial depths will be found.

Very soft deposits may be found below the lakes along the route of the channel. Some indication of this condition was found in test hole DDH-1-58 (Figure 9) where the material was found too soft to sample during drilling.

Proposed Channel

Figure 3 shows the extent of the proposed channel. Figure 4 shows the cross-section of the channel as proposed in an area where rock,

clay and combinations of rock and clay excavation are required. Rock cuts along much of the channel will act as a control of the channel sections.

The contract accepted for the construction calls for conventional methods of excavation rather than dredging. Excavated materials can thus be moved and placed where desired. There should be no problem in keeping waterways clear of sediments during construction. Excavation through existing lakes will require special procedures. The contractor for example plans to drain Grassy Lake to permit excavation. Soft materials on the lake bottom will have to be excavated by drag line if no other procedure proves successful.

The primary factors governing the design of the diversion channel are as follows:

1. A winter discharge of 30,000 cubic feet per second with Southern Indian Lake at elevation 847 feet.
2. Provision for possible subsequent increase in Southern Indian Lake levels to a maximum of 850 feet.
3. The diversion will be operated initially with Southern Indian Lake at elevation 845 feet.

The channel cross-section has been designed on the basis of a limiting velocity of 2.0 feet per second. This limiting velocity is lower than that used for the 2-mile channel (Lake Winnipeg Regulation) which has stiff clay boundaries.

Channel Side Slopes

Vertical side slopes will be used in the rock cuts. The channel in rock will be narrow and deep to compensate for the cross-sectional areas of flow lost by not having sloped side slopes. The criteria for determining

these deepened cuts are shown on Figure 4. The determination will be made as excavation exposes the bedrock surface. The rock cuts will be required to varying depths for about 30% or more of the channel length. The rock cuts will act as non-erodible controls on the flow through the channel.

Excavated rock will provide ideal material for construction of containment dykes for fill placed in low lying areas adjacent to the excavation. This would have been particularly important had dredge-spoil dykes been required. With dry methods of excavation, some dykes may still be required in permafrost areas, and to retain peat etc. The excavation rock will be found useful to provide erosion protection for fill placed adjacent to the channel. It is likely that some rock will be required for slope stabilization measures in areas where very soft soils are encountered.

For cuts in materials overlying bedrock, a six to one, (six horizontal or one vertical) slope has been shown on the drawings issued for tenders. The actual slopes constructed will, however, depend on the conditions exposed by excavation. Essentially some design will have to accompany construction. This is a recognized practice where bedrock, soil-types and extent of permafrost are so variable. Test holes cannot provide sufficient data for design to entirely precede construction.

The 6 to 1 slope is regarded as a reasonable design value for the CI, CH and CL-ML soils encountered. Slopes of 6 to 1 were used for example on the Greater Winnipeg Floodway for soils similarly classified. Permafrost, however, gives rise to more severe conditions for the South Bay-Issett Lake Channel. However, these are partly offset by less severe conditions resulting from operation of the channel with very little fluctuation in water level. In a channel filled with water, buoyancy adds

to the support of the side slopes, and water in the channel reduces seepage gradients through the soils towards the excavation.

Difficulty with permafrost results when rapid thawing occurs in soils having high moisture contents, particulary when the moisture is in the form of segregated ice crystals or lenses. Instability results when thawed water, unable to drain quickly enough reduces soil strength. If the thaw is sufficiently rapid, and the moisture content sufficiently high, sliding takes place even with very flat slopes. The rate of thaw can be controlled by the timing and rate of excavation during warm weather. Within limited scope, this permits some adjustment as to what slopes may be used.

It is considered that side slope instability cannot be entirely avoided. Some instability will likely be evident during the summers of 1974 and 1975 when excavation first exposes the permafrost to thawing. At these times it will be relatively simple to take remedial measures such as using flatter slopes, providing for soil drainage, or the construction of berms. When the channel is filled, heat from the water will be an additional cause for permafrost thawing until such times as thermal equilibrium is restored. The loss of stability from this thawing will be offset to a considerable extent by the buoyant stabilizing effect of water in the channel. Nevertheless, at some locations side slopes may slide due to permafrost melting or water erosion and result in lateral movement of the channel. The tendency for the channel to shift will be limited by the relatively high proportion of the channel in bedrock and will not impose severe damage to the environment.

Erosion

The limiting velocity of 2.0 feet per second used for the channel design may be reasonable for soils undergoing permafrost thaw and also for

silty materials such as the ML and SM soils shown on Figures 8 and 9. The existence of many bedrock outcrops should control the slope of the channel and limit the tendency for lateral shifting as has already been mentioned.

With regard to wave action erosion in the channel, it is likely this will be very limited as the curved geometry of the channel provides shelter from wind giving rise to waves.

Erosion of the channel bed and banks may, however, be severe when the natural rock dyke is opened. The opening sequence for the natural dyke has not been completely finalized to date. The sudden release of water could result in velocities higher than the design velocity of 2.0 feet per second which would cause erosion to take place. This high velocity will, however, be for a short time period and the extent of erosion may not be excessive. Material that is eroded from the bed and banks is expected to eventually deposit in Issett Lake.

Effects of Inundation

Under conditions of no flow, the water level through the channel and at Issett Lake will be the same as that at Southern Indian Lake, that is, initially at 847 and possibly later at 850. There are no houses, roads etc. that will be inundated by the new water level. However, there are reportedly nine graves dating prior to 1920, on the north side of the channel where it joins South Bay. These may require re-location. Along the channel, adjoining low areas will be used for disposal sites for excavated materials. This will limit the extent of inundation. Fill over peat areas will prevent floatation of the peat. Some floatation of peat where the channel enters Issett Lake can be expected. The width of the saddle area in which the channel will be located, is much wider at this location, and more area would have to

be covered than there may be fill to cover the peat. Measures may have to be taken to remove the peat prior to, or after it floats when water levels are raised.

It has been noted (Reference 3) that vegetation was starting to grow on the dredge spoil sites along the eight mile channel where work has been underway during the past two years. Grass, bush and later tree growth can be similarly expected on the deposited fill consisting of excavated clays, especially where mixed with peat. Such growth is desirable in controlling rainfall and snow-melt erosion.

Conclusion

Much of the channel length will consist of bedrock excavation, or will be confined by bedrock outcrops. Because of the rock, the slope of the channel bed will be controlled. Some lateral shift of the channel may result in locations where the side slopes are affected by sliding caused by rapid permafrost melt or erosion. The tendency for the channel to shift will be limited by the high bedrock outcrops and in consequence will not impose severe damage to the environment.

Heterogeneous conditions of bedrock elevation, soil type and particularly permafrost occurrence will require design of the side slopes to proceed as the excavation exposes these conditions.

The excavations of permafrost to a depth of up to 40 feet will afford a unique opportunity to observe and study these frozen materials as they are exposed and then thawed. Provision should be made for engineering observations to be made as the work proceeds. Records of the nature of the permafrost, procedures for excavation, slope stabilizing measures etc. would constitute invaluable research data and information for future northern

construction projects.

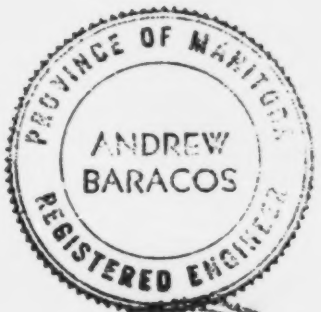
The use of conventional excavation procedures instead of dredging will enable excavation spoil to be placed in confining low areas where it will limit the effects of inundation. Vegetation will likely cover these areas quite rapidly especially where clay soils are mixed with peat.

REFERENCES

1. Baracos, A. Galay V. - "Effects of Increased Flow in the Burntwood River Near Thompson, Manitoba." Lake Winnipeg, Churchill and Nelson Rivers Study Board.

2. Baracos, A. - "Anticipated Shoreline Effects of Raised Lake Levels South Indian Lake , Manitoba". April, 1973.

3. Baracos, A. - Galay, V. "Review of Eight-Mile Channel, Dredge Spoil Studies and Aspects of Channel Operation," January, 1974.



Submitted by:

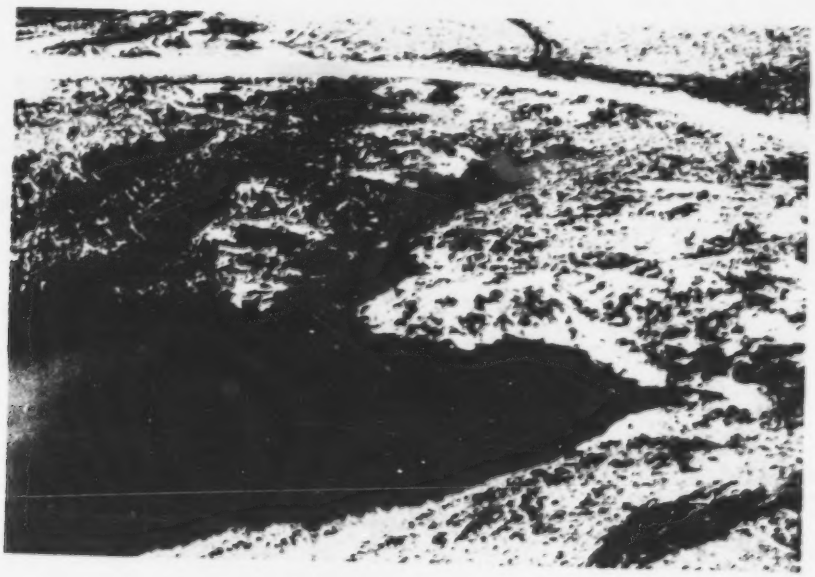
A. Baracos, P. Eng.

V. Galay, P. Eng.

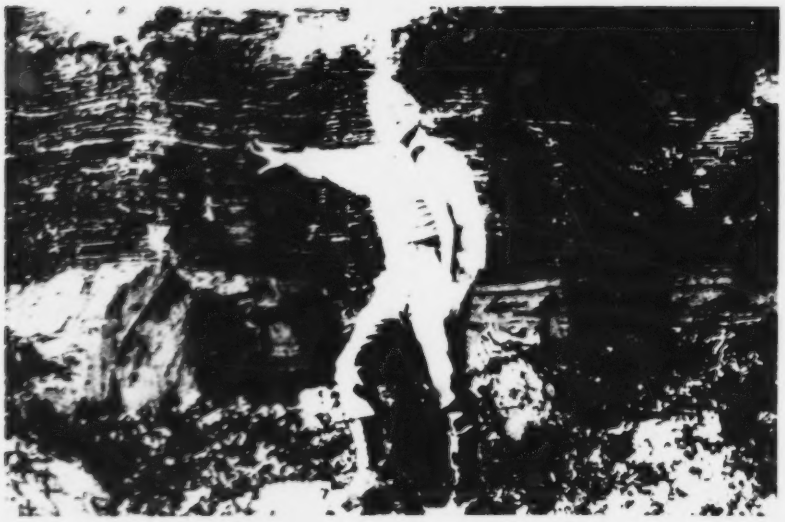
PHOTOGRAPH 2 - (Above right) Aerial view of construction camp and beach on Southern Indian Lake South Bay. The roadway leads across a natural rock dyke that separates the Churchill and Nelson Rivers watersheds.

PHOTOGRAPH 1 - (Above left) Aerial view of an arm of South Bay of Southern Indian Lake that will form part of the channel (Foreground). Shown in the center are the roadway and dyke of Photograph 2. Grassy Lake and Issett Lake can be seen in the background.

PHOTOGRAPH 3 - Arm of South Bay that will form part of channel.



PHOTOGRAPH 4 - Rock dyke forming divide between Churchill and Nelson River watersheds. This dyke will be excavated to permit southerly flow from Southern Indian Lake into Issett Lake.

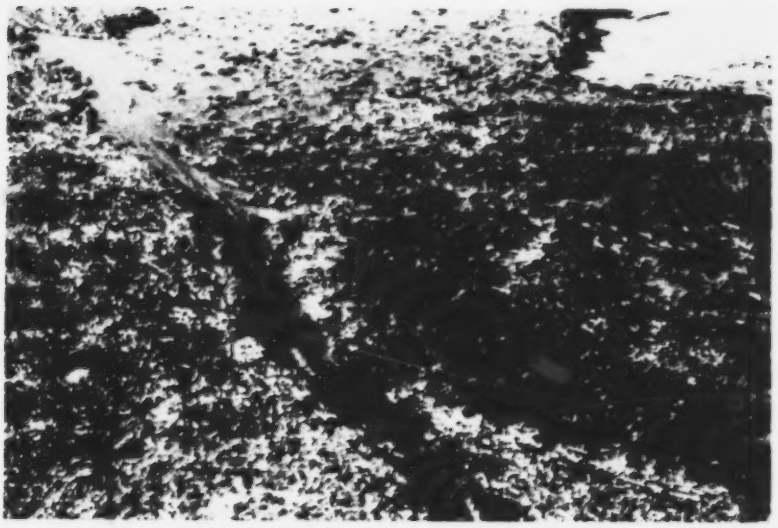


PHOTOGRAPH 5 - Excavated face of borrow pit used to provide road building materials. Note heterogeneous soil conditions. Varved silt and clay are seen over fluvial sands. Immediately adjacent to this area, but not shown in photograph, were glacial deposits of boulders, gravel and sand.

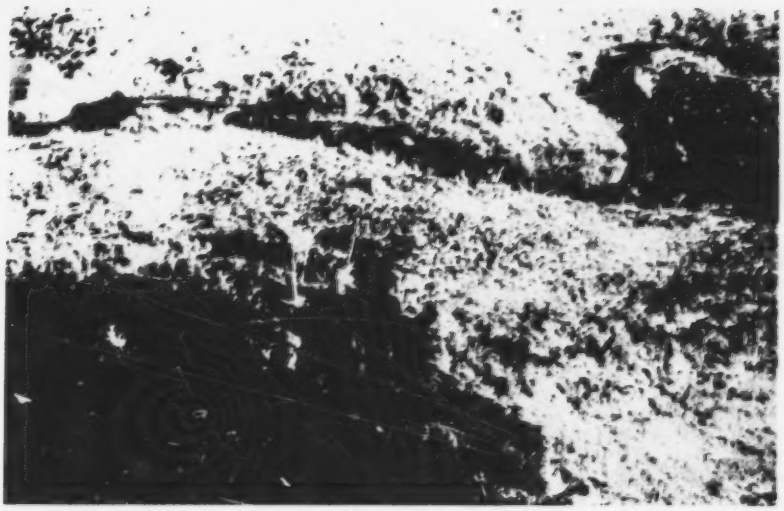
PHOTOGRAPH 6 - Borrow pit clearing. Note relatively shallow excavation over a large area. This type of operation is necessary to provide sufficient material as it thaws and becomes removable by scraper. After completion, a gentle topography remains.

PHOTOGRAPH 7 - Clearing for channel with roadway fill in foreground. Note complete clearing of right of way. Thin Lake can be seen in background. This lake will be incorporated into channel.

PHOTOGRAPH 8 - Sliding along shore line of Grassy Lake. Movement is associated with the thaw of very thick lenses of ice in the permafrost found in this sloped bank. This appears to be a natural phenomena not associated with the present construction.



PHOTOGRAPH 9 - Low lying cleared areas. Note depression caused by vehicle tracks and associated permafrost thaw.



PHOTOGRAPH 10 - Low lying areas adjacent to open water. Note shoreline instability due to permafrost thaw. Drainage of such areas will be required to permit excavation with conventional earth moving equipment.

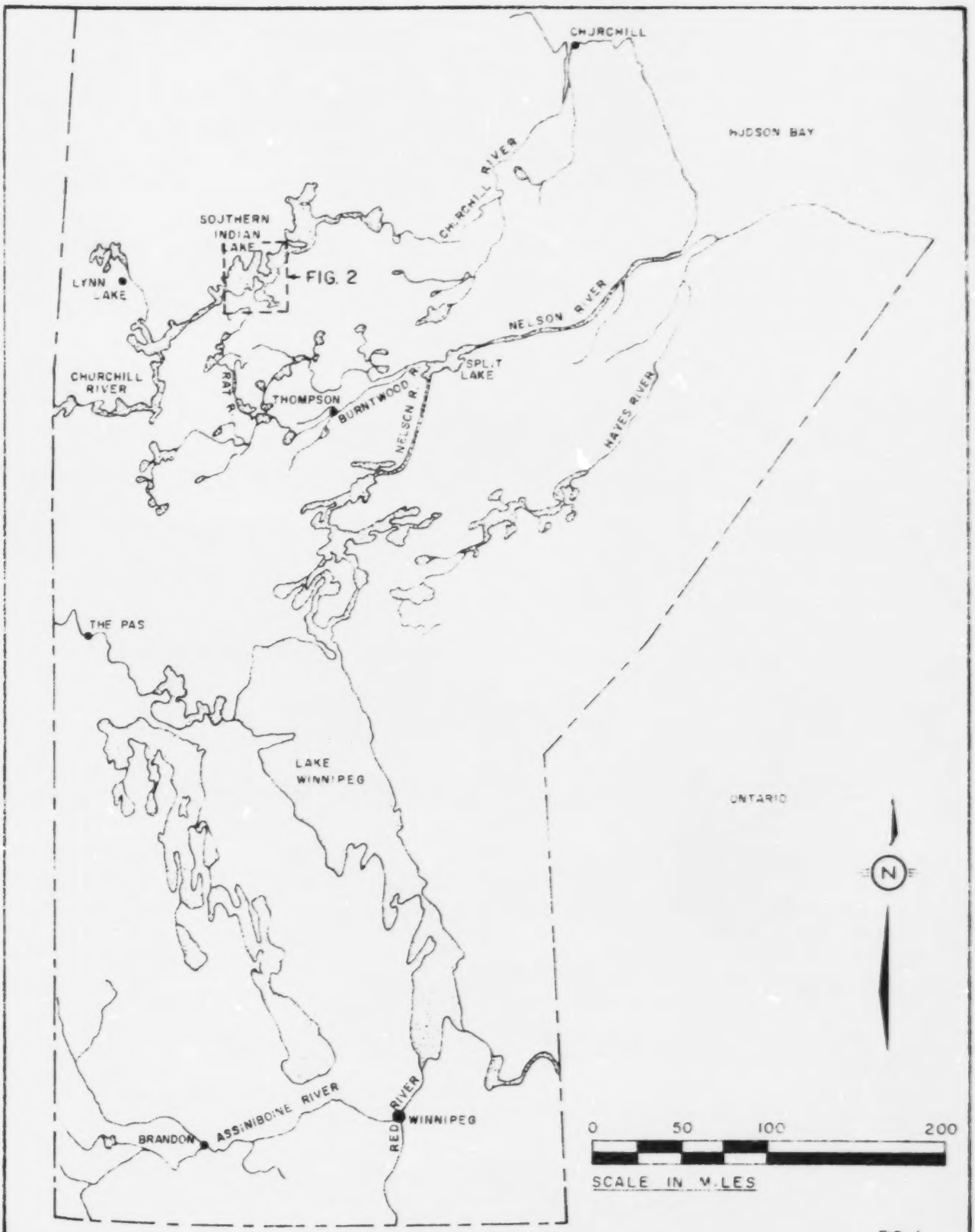


FIG. 1

PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH		CANADA - MANITOBA LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD	
PREPARED	DRAWN CHECKED	SUBMITTED DATE	APPROVED DATE
		SOUTH BAY TO ISSETT LAKE CHANNEL PHYSICAL IMPACT STUDY LOCATION PLAN	
		SCALE AS SHOWN	DATE MAR., 1974
		SHEET 1 OF 9	FILE NO 61-6-1048

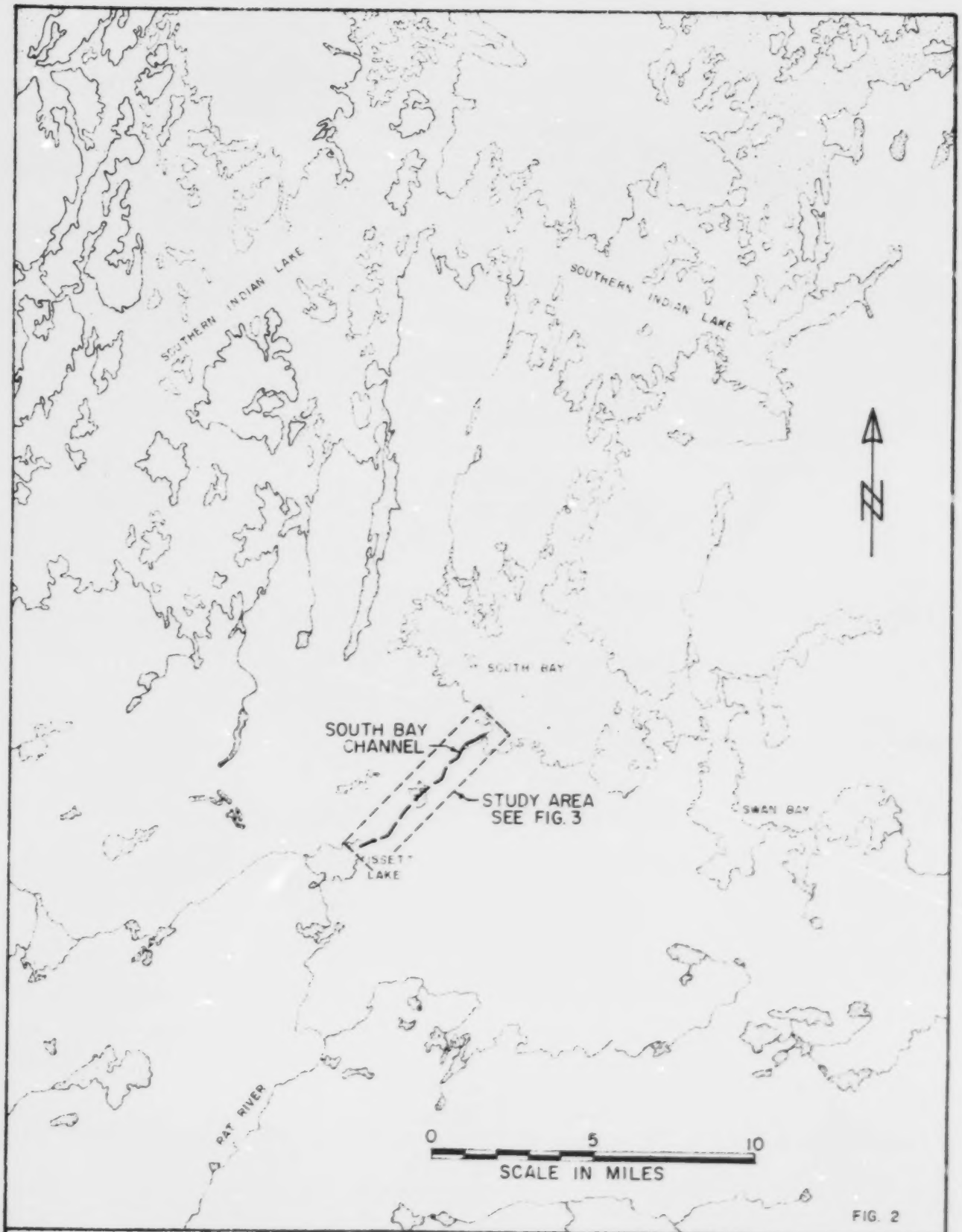


FIG. 2

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

PREPARED	DRAWN	SUBMITTED	APPROVED
	CHECKED	DATE	DATE

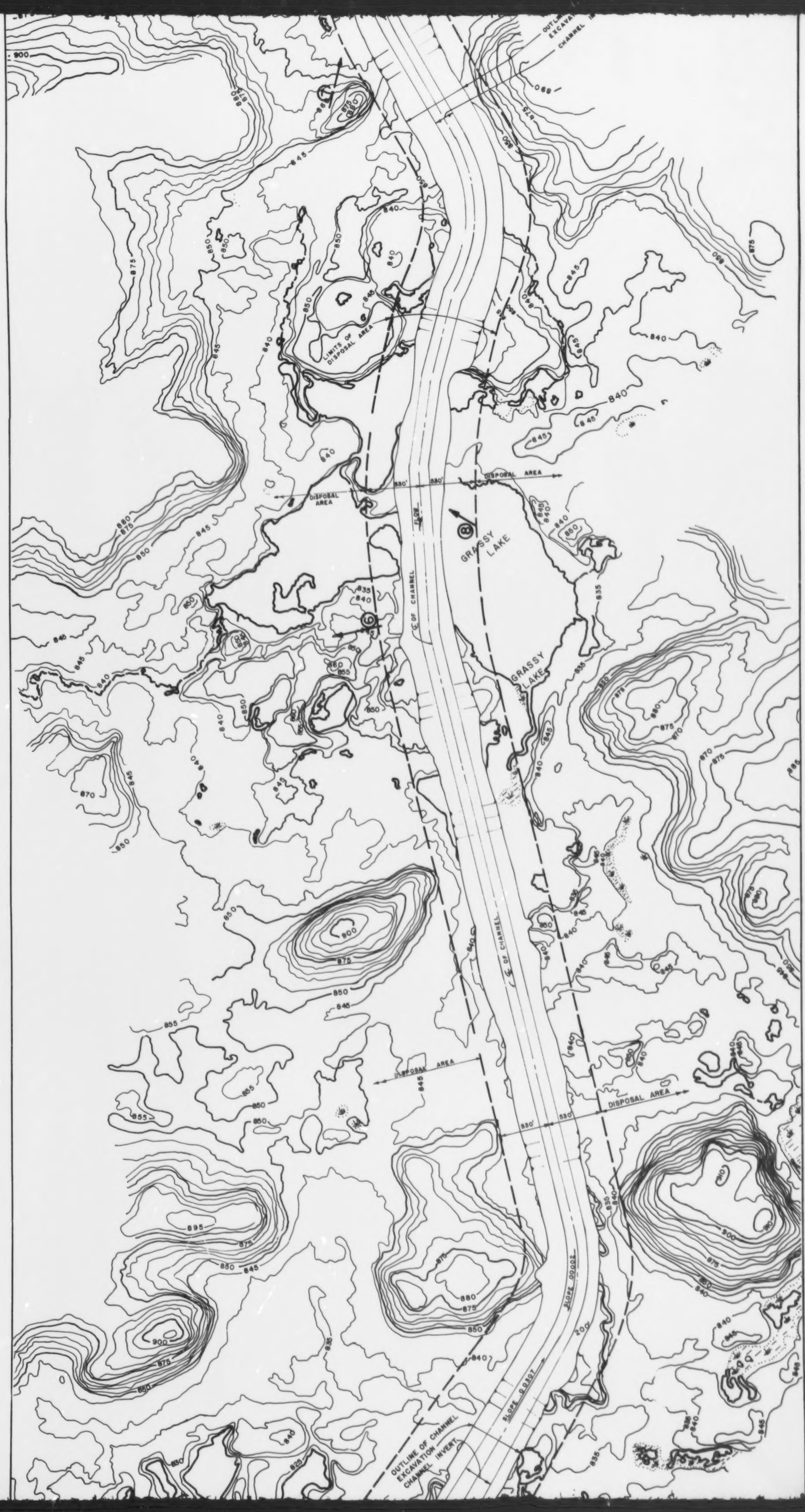
CANADA - MANITOBA

LAKE WINNIPEG CHURCHILL AND NELSON RIVERS STUDY BOARD

SOUTH BAY TO ISSETT LAKE CHANNEL
PHYSICAL IMPACT STUDY
KEY PLAN

SCALE	DATE	DRAWN	FILE NO.

ISSETT LAKE
830
840
825
845
835
840


LIMITS OF DISPOSAL AREA
DISPOSAL AREA
DISPOSAL AREA
GRASSY LAKE
GRASSY LAKE
℄ OF CHANNEL
℄ OF CHANNEL
DISPOSAL AREA
DISPOSAL AREA
OUTLINE OF CHANNEL EXCAVATION
CHANNEL INVERT
SLOPE 0.0197
SLOPE 0.0197

SOUTH INDIAN

SLOPE .0014

FLOW

ROCK BERM

OF CHANNEL

FLOW

SLOPE .0014

SLOPE .0250

OUTLINE OF CHANNEL EXCAVATION

CHANNEL INVERT

DISPOSAL AREA (TYP.)

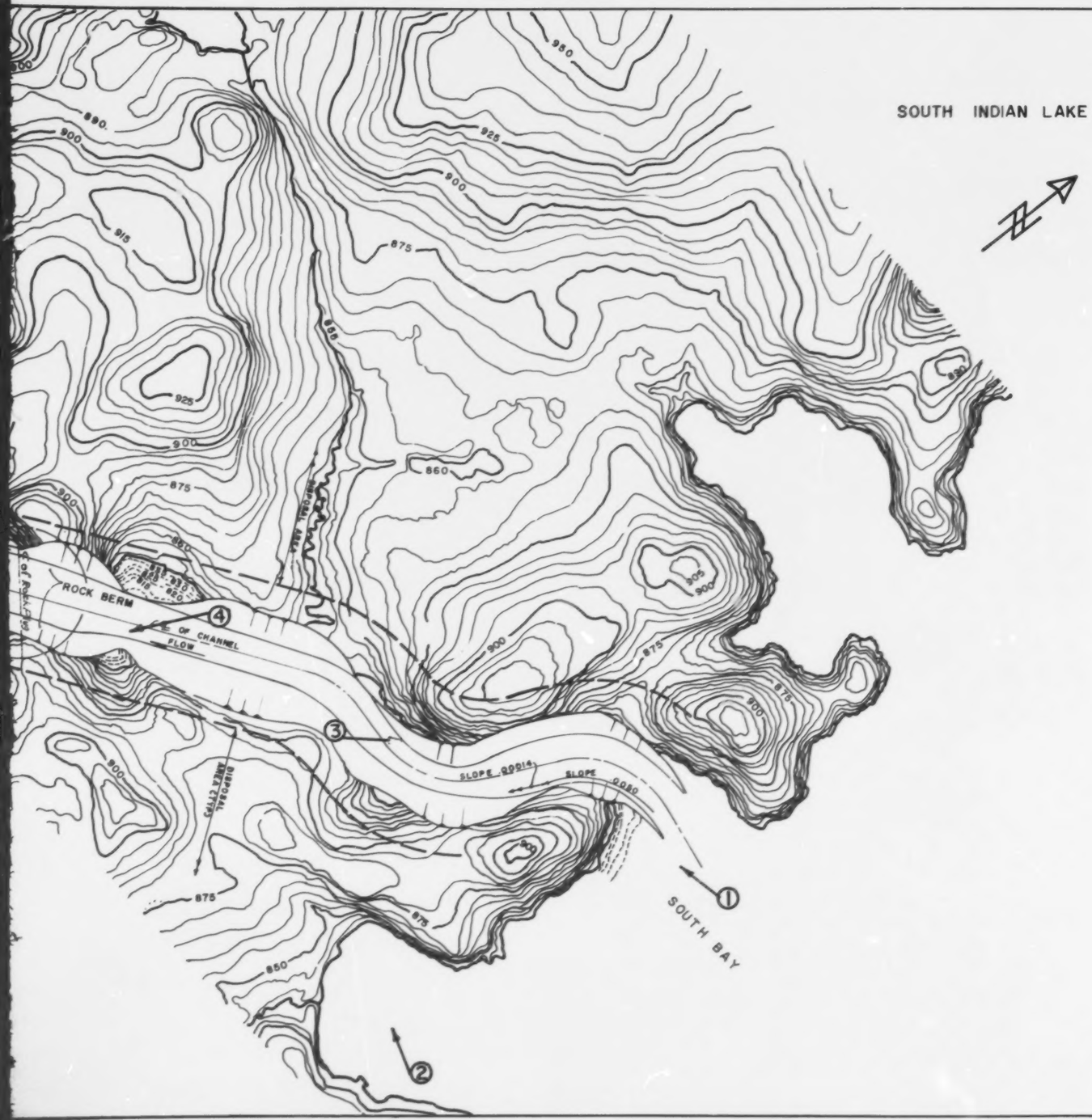
SOUTH BAY

1

2

3

4



NOTE:

LOCATION PLAN AND CONTOUR INFORMATION REPRODUCED FROM MANITOBA HYDRO DRAWINGS No. MH 6188 - 3011, 3012, 3013 JUNE 5, 1973.

LEGEND

⑦ PHOTOGRAPH LOCATION (ARROW INDICATES DIRECTION OF VIEW)

400 0 400 800
SCALE IN FEET

FIG. 3

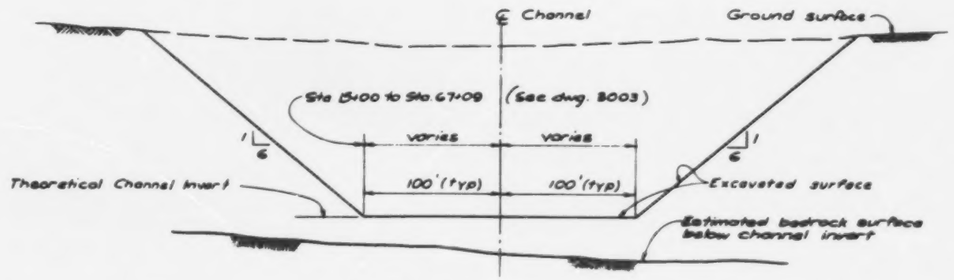
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

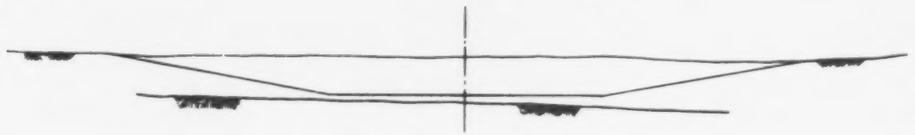
SOUTH BAY TO ISSETT LAKE CHANNEL
PHYSICAL IMPACT STUDY

PLAN OF PROPOSED CHANNEL AND LOCATION OF PHOTOGRAPHS

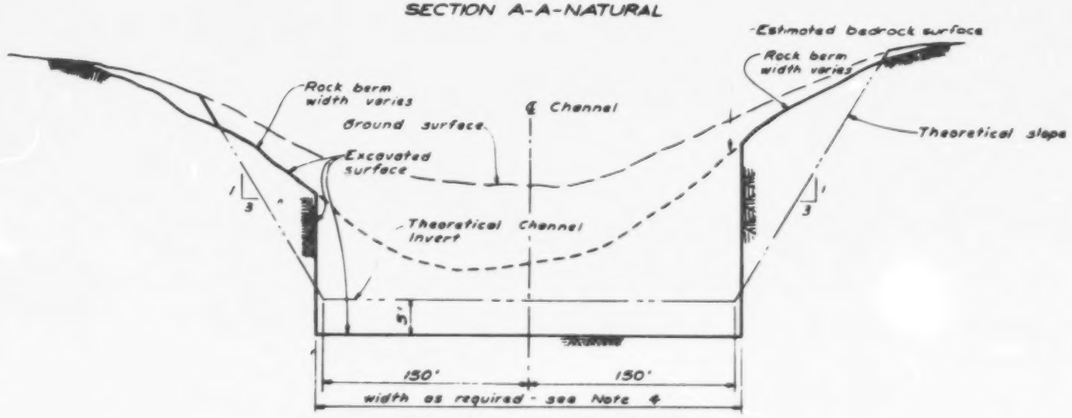
SCALE	DATE	SHEET NO.
	MARCH, 1974	3 OF 9 61-6-1048



SECTION A-A- DISTORTED
(typical for excavations entirely in overburden) /1\

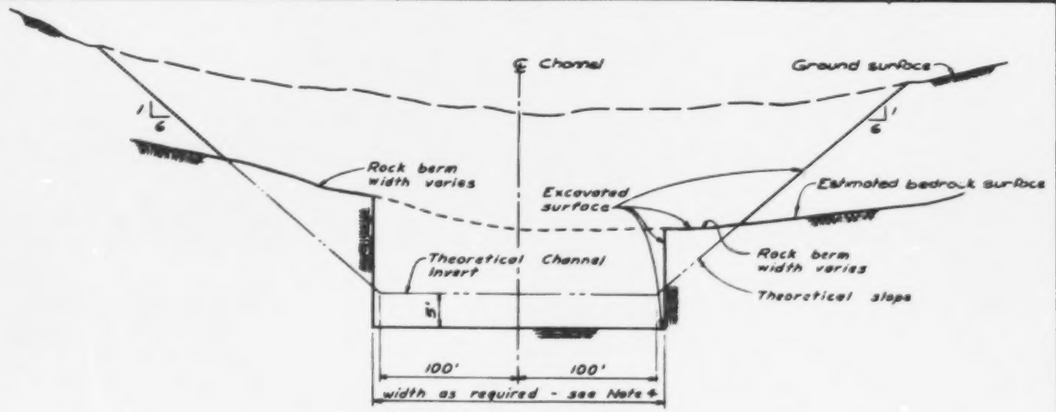


SECTION A-A-NATURAL



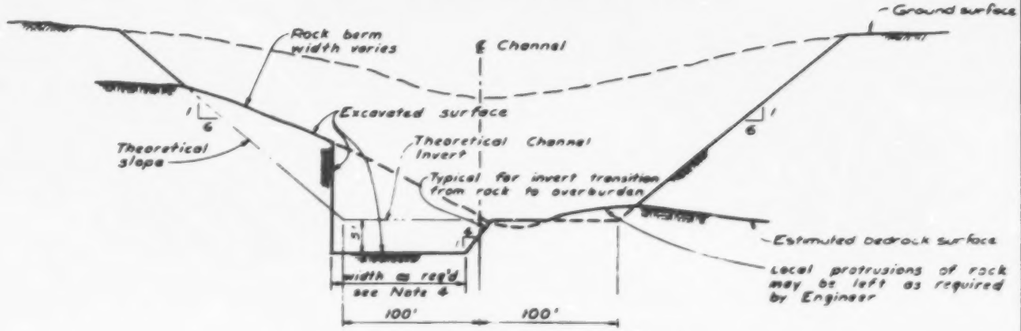
SECTION C-C- DISTORTED
(typical for excavations with nominal overburden on rock berms) /1\

SECTION C-C - NATURAL /1\



SECTION B-B- DISTORTED
(typical for excavations in overburden and rock) /1\

SECTION B-B-NATURAL /1\



SECTION D-D- DISTORTED
(typical for excavations partially in rock) /1\

SECTION D-D- NATURAL /1\

FIG. 4

NOTES:
1. Distorted Sections are: Scale A Horiz., Scale B Vert.
2. Natural Sections are Scale A
3. For theoretical channel invert elevations see dwgs 3003, 3004 and 3005.
4. The theoretical slopes for overburden excavation shall be established using the general criteria shown. Should rock be encountered in the excavation, the lines and grades for rock excavation will be determined by the Engineer such that the cross sectional area of rock excavated approximates the cross sectional area of rock within the theoretical slopes & invert. /1\

Scale A 50 0 50 100 Feet

Scale B 10 0 10 20 Feet

/1\ Sections and notes revised. — June 6, 1973

CRIPPEN ACRES ENGINEERING WINNIPEG MANITOBA

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH BAY CHANNEL
CHANNEL EXCAVATION SECTIONS

SCALE As shown
DWG NO. CAE 205-8
MH 6188
3006
/1\

MATCH LINE

GRASSY LAKES

DDH-22 SB
DDH-23 SB
DDH-24 SB
DDH-25 SB
DDH-26 SB
DDH-340
DDH-341
DDH-342
DDH-343
DDH-344
DDH-345
DDH-27 SB
DDH-28 SB
DDH-29 SB
DDH-535
DDH-536
DDH-537
DDH-538
DDH-539
DDH-555
DDH-556
DDH-557
DDH-558
DDH-532
DDH-533
DDH-534

S10 78-77 DS

S10 C77-09 14

210,359.21 N
184,739.60 E

208,606.69 N
178,238.45 E

ISSETT LAKE

214,000 N

212,000 N

210,000 N

NOTES

1 For notes and legend see dwg 3013

Scale 400 0 400 800 Feet

(DATA FOR TENDERERS) FIG. 5

CRIPPEN ACRES ENGINEERING
WINNIPEG MANITOBA

D. KEIL

DESIGN BY
DRAWN BY
SUBMITTED
APPROVED
APPROVED
DATE June 5, 1973

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH BAY CHANNEL
TOPOGRAPHY AND LOCATION OF EXPLORATORY HOLES
SHEET 1 OF 3

SCALE As shown
DWG NO. CAE 205-B, MH 6188
3011
REVISIONS

W.R.B. SHEET 5 OF 9

61-6-1048

MATCH LINE

WDDH-7

Sta 241+16.85

DDH-7SB

Sta 236+23.11

WDDH-8

DDH-8SB

DDH-9SB

222,830.00 N
193,830.00 E

THIN LAKE

WDDH-9

WDDH-10

DDH-10SB

DDH-11SB

WDDH-11

WDDH-12

WDDH-13

Sta 215+24.15

23,720.85 N
191,856.79 E

Sta 203+08.79

DDH 549

DDH 550

WDDH-14

DDH-12SB

DDH-13SB

WDDH-15

WDDH-16

WDDH-17

NDDH-8

Sta 191+05.58

DDH-14SB

DDH-15SB

NDDH-9

219,098.76 N
191,302.56 E

DDH-16SB

WDDH-17SB

28,735.26 N
190,405.96 E

WDDH-21

DDH-18SB

2 8,276.94 N
189,702.01 E

DDH-20SB

DDH-19SB

27,671.89 N
188,982.43 E

GRASSY LAKE

216,376.01 N
187,972.61 E

DDH-21SB

MATCH LINE

222,000 N

220,000 N

218,000 N

216,000 N

185,000 E

190,000 E

195,000 E

NOTES
1 For notes and legend see dwg 3013.

FIG. 6

Scale 400 0 400 800 Feet

(DATA FOR TENDERERS)

CRIPPEN ACRES ENGINEERING
WINNIPEG MANITOBA

DESIGN BY D.Z.
DRAWN BY J.P.
SUBMITTED
APPROVED
APPROVED
DATE June 5, 1973

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH BAY CHANNEL
TOPOGRAPHY AND LOCATION OF EXPLORATORY HOLES
SHEET 2 OF 3

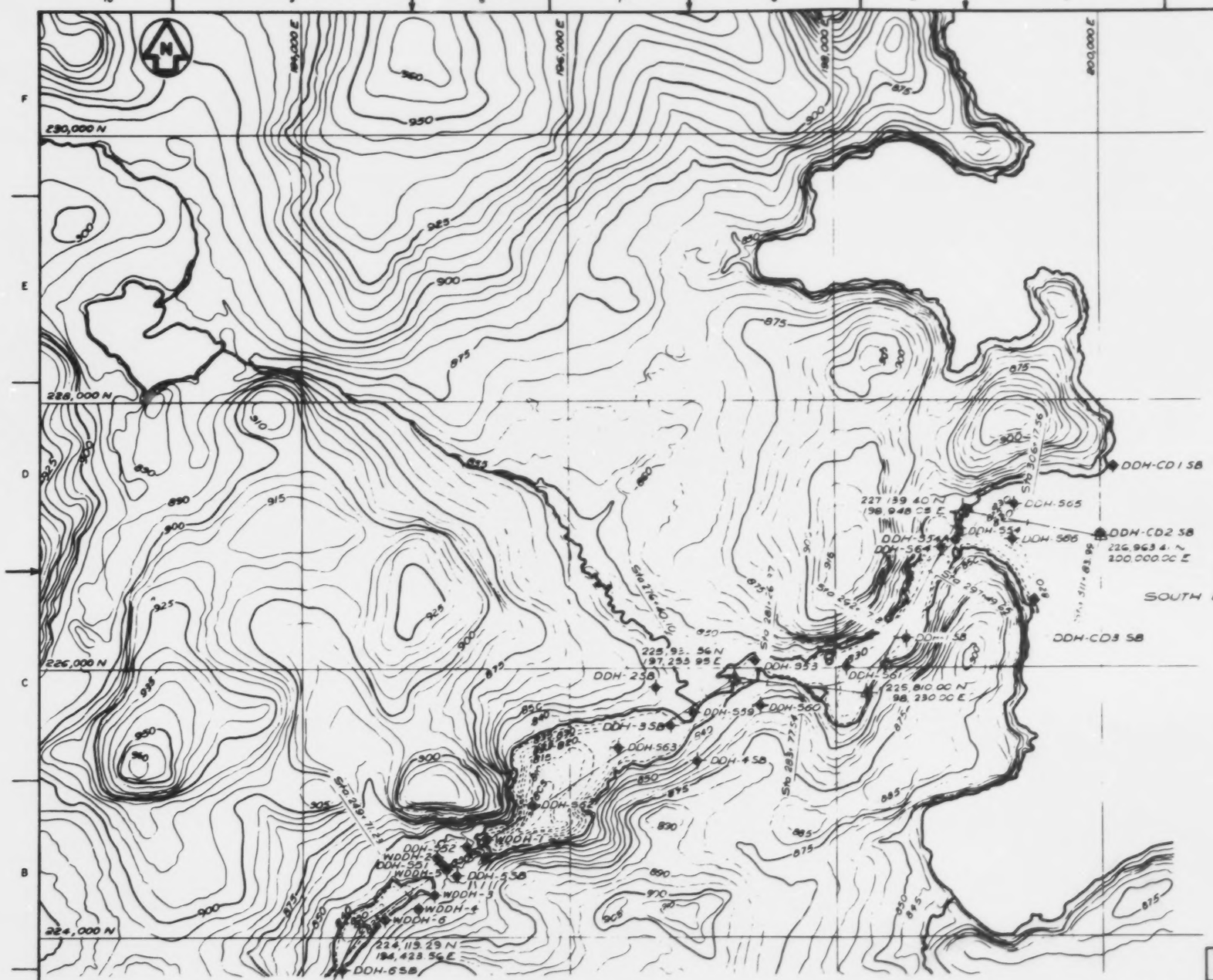
SCALE As shown
DWG NO. CAE 205-B / MH 6188
3012

REVISIONS

3012

WPB SHEET 6 OF 9

61-1-104B



NOTES

1. WDDH-1 to WDDH-20 drilled in 1957 by Water Resources Branch.
2. DDH-138 to DDH-2938 drilled in 965 by Gibb, Underwood McLellan.
3. DDH-531 to DDH-566 drilled in 1971 by Manitoba Hydro.
4. DDH-CD158 to DDH-CD338 drilled in 1973 by Manitoba Hydro.
5. Datum for Drill holes WDDH-1 to WDDH-20 approximate.
6. Topography is referenced to CRD datum, 1973 revision.

LEGEND

- Point of intersection of tangents with coordinates indicated.
- Drill hole.

FIG. 7

Scale 400 0 400 800 Feet

(DATA FOR TENDERERS)

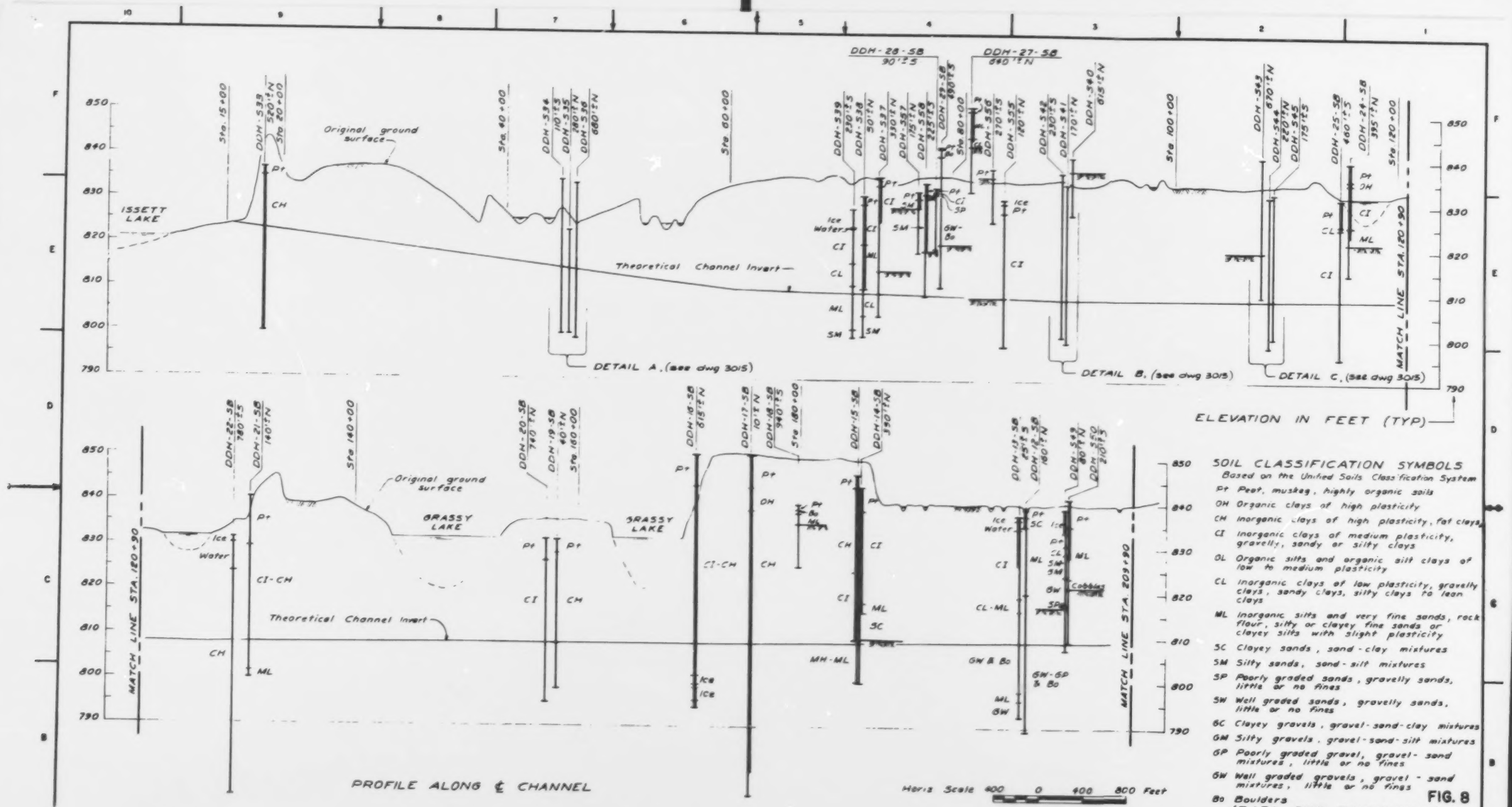
CRIPPEN ACRES ENGINEERING
WINNIPEG MANITOBA

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH BAY CHANNEL
TOPOGRAPHY AND LOCATION OF EXPLORATORY HOLES
SHEET 3 OF 3

DESIGN BY VSK
DRAWING BY S.A. AK
SUBMITTED VSK
APPROVED
APPROVED L.R. Dana
DATE June 5, 1973

SCALE As shown
DWG NO. CAE 205-B, MH 6188
SIZE

W.R.B. SHEET 7 OF 9 61-1-1048



PROFILE ALONG ℄ CHANNEL

SOIL CLASSIFICATION SYMBOLS

Based on the Unified Soils Classification System

- Pt Peat, muskeg, highly organic soils
- OH Organic clays of high plasticity
- CH Inorganic clays of high plasticity, fat clays
- CI Inorganic clays of medium plasticity, gravelly, sandy or silty clays
- OL Organic silts and organic silt clays of low to medium plasticity
- CL Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays to lean clays
- ML Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
- SC Clayey sands, sand-clay mixtures
- SM Silty sands, sand-silt mixtures
- SP Poorly graded sands, gravelly sands, little or no fines
- SW Well graded sands, gravelly sands, little or no fines
- GC Clayey gravels, gravel-sand-clay mixtures
- GM Silty gravels, gravel-sand-silt mixtures
- GP Poorly graded gravel, gravel-sand mixtures, little or no fines
- GW Well graded gravels, gravel-sand mixtures, little or no fines
- Bo Boulders

FIG. 8
(DATA FOR TENDERERS)

LEGEND

- Bedrock
- Permafrost encountered during exploratory drilling

NOTES

1. For location of drill holes see dwgs. 3011, 3013 and 3015
2. All drill holes projected on profile through ℄ of channel. Approximate distances of drill holes from ℄ channel as shown
3. Drill holes WDDH-1 to WDDH-20 not shown

CRIPPEN ACRES ENGINEERING WINNIPEG MANITOBA

MANITOBA HYDRO

CHURCHILL RIVER DIVERSION

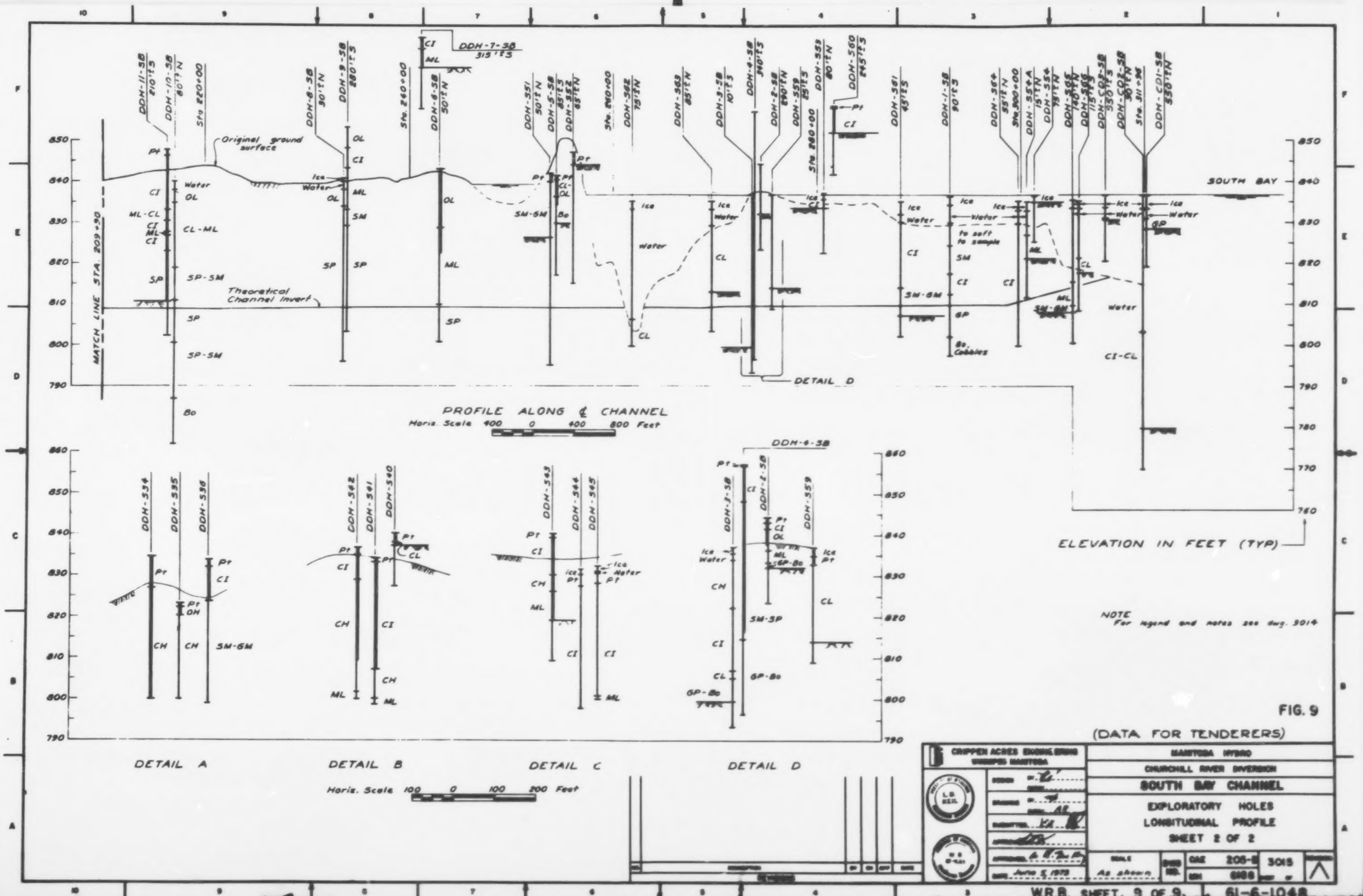
SOUTH BAY CHANNEL

EXPLORATORY HOLES
LONGITUDINAL PROFILE
SHEET 1 OF 2

SCALE As shown | DWG NO. CAE 205-8 3014 | DESIGN | DRN GMH 6/73 | CHK | APPD | APPD L. C. Dyer M.E. | DATE June 3, 1973

W.R.B. SHEET 8 OF 9

61-6-1048



NOTE
For legend and notes see dwg. 3014

FIG. 9

(DATA FOR TENDERERS)

CRIPPEN ACRES ENGINEERING WINNIPEG MANITOBA

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH BAY CHANNEL
EXPLORATORY HOLES
LONGITUDINAL PROFILE
SHEET 2 OF 2

L.B. KEIL

W. R. B. 1978

SCALE As shown
DWG. NO. CAE 205-E 3015
SDI 6486

W.R.B. SHEET 9 OF 9. 61-6-104B

APPENDIX 2 - Vol. 1 - F

ANTICIPATED EFFECTS OF THE CHURCHILL RIVER DIVERSION PROJECT ON THE ICE COVER OF SOUTHERN INDIAN LAKE

ANTICIPATED EFFECTS OF THE CHURCHILL RIVER DIVERSION PROJECT ON THE ICE COVER OF SOUTHERN INDIAN LAKE

by

F. PENNER
Planning Division, Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba
February, 1974

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

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ABSTRACT

The condition of the existing ice cover on Southern Indian Lake and the demand placed upon the ice cover for transportation purposes was ascertained by a field inspection and by interviewing knowledgeable local people. The probable condition of the ice cover under future diversion conditions was then estimated by analysing available data and by reference to previous work by others.

The condition of the existing ice cover, although in part marginal, was found to be generally adequate to meet the demands of transportation. The probable condition of the ice cover under future diversion conditions was found to be generally improved over the Lake except in the vicinity of the South Indian Lake Settlement where the ice cover would become poor or non-existent.

The best available estimate of the future condition of the ice cover within the area of the Settlement indicates that an ice crossing safe for bombardier travel will probably form at one location but that the safe crossing may form considerably later in the winter than at present. The uncertainty as to the quality of the ice cover and the time of its formation suggest that contingency planning for a case of no safe ice crossing is warranted at least until experience indicates otherwise.

RECOMMENDATIONS

It is recommended that planning for at least the first year of the diversion assume that no safe ice crossings will exist for a distance of 4 miles north and 4 miles south of South Indian Lake Settlement. It may be prudent to utilize a pontoon bridge or ferry system for one or more years until the need for a permanent higher cost crossing can be ascertained from observation of the quality of the ice cover under diversion conditions.

OBJECTIVE

The objective of this study is to determine the condition of the existing winter ice cover on Southern Indian Lake as it affects transportation and to estimate future changes in condition due to the Churchill River Diversion Project. Additionally, measures to mitigate damages and to enhance benefits will be proposed.

TERMS OF REFERENCE

The ice cover on Southern Indian Lake is used extensively as a road bed for winter transportation especially in the vicinity of the settlement, South Indian Lake. After diversion the main flow of the Churchill River will be re-routed through the narrow neck of water that divides the South Indian Lake community. The high velocities associated with the diverted flow past the community will at best allow a weak ice cover to form, if at all. This ice regime change will significantly affect the ability to travel freely between the two sections of the settlement in winter. Altered flow patterns throughout the lake could also change the ice regime along the winter ice roads.

This study consists of an an assessment of the effect that the diverted Churchhill River has on:

a) the ice regime in the vicinity of the community, South Indian Lake, and

b) the ice regime in the remainder of Southern Indian Lake with particular attention to the over ice transportation routes.

Water levels and flows were taken from Reference I. For the purpose of this study it was considered adequate to represent the sequence of water levels (or flows) during a typical year by the successive water levels (or flows) having a frequency of occurrence of 50%. Modified historic conditions were taken to be "natural conditions". The sequence of levels for a typical year for natural and regulated conditions are shown on Figure I. The sequence of flows for a typical year under natural and regulated conditions are shown on Figures 2A and 2B.

The condition of the existing and future ice cover was assessed largely in terms of the present day demands placed upon it. However, future changes in demand, where discernible, were recognized was well.

Because time and funds for this study were minimal, it was necessary to limit the study to identified critical elements of the problem and to make maximum use of existing information. The report is, therefore, to a large extent a synthesis and summary of work done by others.

STUDY AREA

The study area includes Southern Indian Lake and Opachuanau Lake. A key plan of the study area is included as Figure 3, a plan of the Lakes to a scale of 1:250,000 is included as Figure 4, and a detailed plan of the South Indian Lake Settlement is included as Figure 5A.

The study area extends from latitude 56° 30'N to 57° 40'N and from longitude 98° 10'W to 100° 00'W. The combined surface area of the existing lakes is 900 square miles. The mean depth of the lakes is about 30 feet while the maximum depth is about 120 feet.

Ice normally begins to form in sheltered bays on about October 15 and has formed on the main body of the lake by about November 15. The ice cover break-up begins in the narrower channels in the southern areas on about May 15 and is essentially complete in the northern areas by June 15.

The only permanent community in the study area is the South Indian Lake Settlement situated on either side of and on islands within the narrow channel joining South Bay to the main portion of Southern Indian Lake. The Settlement has a population of approximately 600 persons some of whom engage in fishing on the lake and/or trapping around the lake. Access to the Settlement is by aircraft from Thompson or Leaf Rapids, or by boat or winter road from Leaf Rapids. An all-weather road is currently under construction from Leaf Rapids to the Hydro Camp at South Bay about 8 miles from the Settlement.

METHODOLOGY

General Approach

The following approach was adopted:

1. Identify transportation demands on winter ice cover on Lake.
2. Determine existing condition of ice cover as related to transportation demand.
3. Estimate future condition of ice cover as related to transportation demand.
4. Consider means of mitigating damages and enhancing benefits.

Transportation Demand on Ice Cover

South Indian Lake Settlement: The existing and future settlement are outlined in Figures 5A and 5B. The houses are located on either side of, and on islands within the "Narrows". The existing school is on the west side while the future school will be on the east side. Trails are few and roads almost non-existent. Hence, the life of the community requires continual crossing of the Narrows as well as transportation along the Narrows between origins and destinations on the same side of the Narrows. The existence of schools, nursing station and churches almost requires the capability of crossing the Narrows at least by walking or canoe each day of the year. Increased emphasis on regular school attendance with associated bussing of children by bomardier or boat is increasing transportation demands. The time of the change-over from water to ice transportation is likely not critical since this varies from year to year in any case. However, the duration of the interval from the end of one form of transportation to the beginning of the other is likely of great importance. With

the establishment of the road to Leaf Rapids and to the Hydro Camp at South Bay, over-land (or over-water) transportation is to the west. The proposed shift of the Settlement to the east side of the Narrows will create an increased demand for crossing the Narrows.

Normal winter transportation within the village is by walking or power toboggan which requires about 2 to 4 inches of ice. The school bus and commercial fishery transport utilize bombardiers which require about 8 inches of ice. The winter supply of gravel, construction material and fuel utilizes heavy trailer trucks which require about 40 inches of ice. In the winter time aircraft land on the ice in the Narrows opposite the Hudson Bay Post on the west side of the Narrows largely because most of the passengers and freight are destined for this area.

Domestic Winter Fishery: This fishery is confined to an area approximately 4 miles square north of the north end of the Narrows as shown on Figure 4. It likely demands power toboggan travel along the Narrows and over the fishing area. Daily travel is not likely a requirement and interruptions of 1 or 2 weeks are probably not critical. However, travel during most of the year is likely desirable.

Commercial Winter Fishery: This fishery is confined to the area north of latitude 57°00'N or north of Camp 9 as shown on Figure 4. The fishery begins about January 15 and continues to about April 15. The transportation demand is for bombardier travel over most of the fishery area to collect fish and to transport them south through the Settlement and west to the packing plant at Leaf Rapids.

Fur Trap Lines: Registered trap lines cover all of the shorelines and islands of the lake. A trap line is an area of irregular shape typically 10 miles long and 20 miles wide. Trappers typically leave for their trap lines on about October 15 under open-water conditions and return on about December 15 under ice conditions. Although the trapping activity requires crossing creeks and bays, these crossings apparently are not a great impediment since they change from open-water to safe ice in a few days. In spring, trappers leave for their trap lines on about April 15 (at the end of the winter fishery) under ice conditions and return after about June 15 under open-water conditions. The time of the change from water to ice or from ice to water is likely not critical since this varies from year to year in any case. Of greater importance would be the duration of the interval between the end of one form of transportation and the beginning of the other.

Condition of Existing Ice Cover

South Indian Lake Settlement: The existing condition of the ice cover in the Settlement area was determined by interviewing local residents for experience data and by analysing school attendance and bus records.

The water in the Narrows freezes over on about October 31. Freeze-over is rapid. The interval from the end of the use of boats in open-water to the beginning of the use of the ice cover is roughly as shown in Table I.

An attempt was made to confirm verbal reports on experience data by analysing school records. The most reliable data are school bus records shown in Table II. The school bus record may be taken to indicate an interruption of safe or "no risk" transportation for a period of 2 weeks in fall and 3 weeks in spring. The attendance record of selected students who need to cross the Narrows to go to school is shown in Table III. The table

indicates that students cross the Narrows to attend school even if the bus does not operate. The data suggest that students typically miss 2 to 4 days of school because of the fall freeze-up period. This agrees with reports of the teachers. The grade I attendance record in Table IV also reflects the freeze-up period. For example, the 1972 fall freeze-up effect is evident on October 16 to 20 on Table IV, on October 16, 17, 18 on Table III, and on October 17 to November 2 on Table II. Similarly the 1971 fall freeze-up effect is evident on October 28 to November 5 on Table IV, and on October 28 to November 5 on Table III. In summary the school statistics tend to confirm the verbals reports of local residents.

The ice thickness throughout the Narrows is generally uniform and adequate for the demands imposed upon it except that the ice opposit Andrew's Point and opposite the north cemetery is considered marginal for bombardier travel at any time. These areas are shown on Figure 5A. At Andrew's Point it is necessary to travel along the shoreline where the ice freezes to the bottom or along the east side of the Narrows. Opposite the north cemetery it is necessary to travel along the east shoreline where the ice is frozen to the bottom.

Spring break-up begins about May 15, although the ice is weakened and unable to carry heavy loads for some weeks before that date. Open water first appears opposite the north cemetery, opposite Andrew's Point and on either side of Clee Island opposite the Hudson Bay Company Post suggesting that water currents affect the ice cover even under existing conditions. The duration of the break-up period is difficult to ascertain, but appears to be slightly longer than the fall freeze-up period.

The only loss of life by drowning during the freeze-up or break-up period appears to have occurred on May 8, 1973 when two boys drowned after a power toboggan broke through the ice. Apparently the local people understand and have adjusted to the ice regime.

The ice cover during February and March appears adequate for heavy supply trucks coming in via South Bay although it may be necessary to clear snow or pack snow to increase the ice thickness or to avoid certain areas of weaker ice.

The winter ice is adequate for landing aircraft opposite the Hudson Bay Company Post or opposite the proposed town centre site. Shown on Figures 5A and 5B.

The ice cover from the Settlement west to Leaf Rapids is generally adequate for bombardier travel, although a number of over-land portages are necessary to avoid open-water or weak ice. The route normally followed is shown on Figure 4.

Domestic Winter Fishery: The ice cover in the area of the domestic winter fishery is adequate for power toboggan travel, but some caution needs to be exercised when travelling by bombardier. However, doubtful areas can be identified and avoided without undue difficulty.

Commercial Winter Fishery: The normal bombardier route from the winter fishery through the Settlement to Leaf Rapids is shown in Figure 4. Bombardiers travel freely over the area during the fishing seasons with the following exceptions:

1. The area east of the islands opposite Missi Falls is not travelled.
2. The area east of Long Point is not travelled.
3. Caution is exercised and testing is required when travelling across the channel south of Long Point.

4. Caution is exercised and the defined route is followed when travelling between Camp 9 and the Settlement. The first 2 miles south of the Long Portage are the most critical. The lake east of this route is avoided because of poor ice.

It is of interest to note that the winter trail used earlier by Lamb to haul frozen fish by tractor train (also shown on Figure 4) avoids the main channel between Camp 9 and the Settlement entirely. The confirms to experience of the bombardier operators.

Fur Trap Lines: The transportation demands of the trapping industry are not severe, and the existing ice cover apparently is adequate to meet these demands. Possibly this is because the trapping season spans the freeze-up and break-up periods and the trappers have adjusted to variable ice conditions.

Condition of Future Ice Cover

Basis of Estimate: Estimates of ice cover conditions are usually made on the basis of a heat budget - an analysis of the quantities of heat introduced into or lost from a body of water - and/or on the basis of the velocity of water currents. The effect of a change in the level or flow regime may be estimated from the associated change in heat budget or in the velocity of water currents.

Analysis of Water Temperature: The significance of the heat introduced into Southern Indian Lake by the Churchill River was deduced from data published by the Fisheries Service (Reference 2 and 3). The lake was divided into eight regions as shown on Figure 6. Water temperatures were measured at the stations shown on Figure 6. The Churchill River now flows

from Leaf Rapids through Regions 0, 1,2,3 and 4 to Missi Falls as shown on Figure 7. Regions 5, 6 and 7 are not influenced by the existing flow of the Churchill River. Under diversion conditions the winter flow of the Churchill River will be from Leaf Rapids through Regions 0 and 1, into 2, then south through Region 6 to the South Bay Channel as shown on Figure 8. Then the eastern half of Region 2 and Regions 3 and 4 will be isolated from the main stream winter flows. Regions 0, 1 and the western half of 2 will be unaffected by the diversion.

The effect of the flow diversion on the water temperature may be estimated from the data in Table V. The temperature at Station 09 may be taken to represent the temperature of the Churchill River inflow. In the winter time, the temperature of the inflowing water as measured at Station 09 is closely the same or slightly lower than that of Southern Indian Lake as measured at Stations 10, 20, 30, 40 and slightly lower than the temperatures measured at Stations 50 and 60 which are not affected by the Churchill River flow. It appears that the Churchill River flow has a slight cooling effect on the lake in the winter time.

The effect of the diversion of the flow on Region 6 may be estimated by assuming that the temperature at Station 60 under diversion conditions would be the same as the temperature at Station 20 under existing conditions. Reference 3 indicates that the exchange time for the water in Region 6 under diversion conditions is only 12 days. That is, the winter temperature would drop about 1 to 2^{o}C while the summer water temperature would remain about the same as under existing conditions.

The effect of the diversion of flow on Regions 2 east, 3 and 4 may be estimated by assuming that the water temperatures at Stations 30 and 40 under diversion conditions would approach the temperatures at Stations 50 and 60 under existing conditions. That is, the winter water temperature might be

about 1°C higher due to the removal of the cooling effect of the Churchill River water while the summer water temperatures would be unchanged.

The preceeding temperature changes are small and will not likely have noticeable effects on the ice conditions. The effect of normal variations in temperature and snow conditions from one year to the next will be much greater.

Cleugh (Reference 2) has computed a heat budget for the lake for existing conditions. During the period of greatest heat gain (from May 31 to July 11) the Churchill River water was found to contribute 1.3% of the total heat added to the lake. If only Region 1 was considered as receiving heat from the Churchill River, then the river supplied approximately 2.7% of the total heat gained. This confirms that the Churchill River does not have a major influence on water temperatures.

In summary, it is believed that the effect of the diversion on water temperatures will be minor, that this effect would tend to improve ice conditions in Region 6 and worsen ice conditions in Regions 2 east, 3 and 4, but that the effect of changes in water temperature on ice conditions would be masked by the greater effect of changes in water current velocity on ice conditions.

Analysis of Water Current Velocities: The effect of changes in water current velocities on ice cover was analysed by computing existing velocities at cross-sections where the condition of the existing ice cover was known to establish a relationship between current velocity and condition of ice cover. The locations of the cross-sections are shown on Figures 4 and 5A and the results of the calculations are presented in Table VI. Photographs of some of the cross-sections are included in this report.

It should be mentioned that some of the data (marked with a question mark in Table VI) are based on very approximate estimates. Similarly the condition of the ice cover is not known with precision. Hence, the data yield only an approximate relationship which may be summarized as shown in Table VIII.

The ice cover for any given velocity is poorer than one would expect on the basis of experience elsewhere. Cross-Section 14 east of Long Point has a very low velocity (0.11 ft/sec) yet all fishermen questioned observed that the ice here was not safe for a bombardier crossing. In some winters, areas of open-water had been observed here.

The velocity at Cross-Sections 15 and 16 in the Narrows area was computed to be 0.02 ft/sec based on a typical drop in lake level of 0.4 ft. per month and 0.14 ft/sec based on a probably maximum change in lake level of 0.1 ft. per day due to the atmospheric pressure differences. The ice in the centre of the channels at either side of the island at Cross-Section 15 is reported to be unsafe for bombardier travel. Similarly the ice opposite Andrew's Point at Cross-Section 16 is reported to be marginal for bombardier travel. The effect of currents on ice conditions in the Narrows is substantiated by reports that open-water first appears in spring in the narrowest sections.

The velocities at a number of cross-sections under diversion conditions were also calculated and the corresponding condition of the ice cover estimated on the basis of the relationship established previously. The locations of these cross-sections are shown on Figures 4 and 5A and the computed velocities and estimated condition of ice cover shown in Table VII.

Manitoba Hydro has prepared an estimate of probable ice conditions under diversion conditions for the channel through the South Indian Lake Settlement. The results of this estimate are shown on Manitoba Hydro Dwgs. 0531-E-0105 (2 sheets) which are reproduced in reduced form on Figure 9. This is the best estimate of future conditions which is available at this time.

South Indian Lake Settlement: The estimated ice conditions under diversion conditions are shown on Figure 9. It is anticipated that there will only be one place within the Settlement where a safe ice crossing may form. This probably will be safe for bombardiers but not for heavy trucks. It will be possible to cross from one side of the Narrows to the other by going further out on the lake north and south of the Narrows.

The condition of the shelf ice along the shoreline is likely to be variable over the length of the Narrows. In the narrower channels where velocities are greatest little shore ice may form and boats or ferries might be able to dock all winter although special docking facilities or techniques may be required because of the current. The maximum current velocity would not exceed about 1.2 miles per hour and should not create difficulties for small power boats. In the wider channels substantial shore ice will form and prevent docking of boats. It is unlikely to be possible to travel along the shore ice for the full length of the Narrows.

Domestic Winter Fishery: The condition of the ice in the area of the domestic winter fishery will likely change little north of the islands at the mouth of the Narrows. The increase in lake level will cause a small improvement in ice condition. However over-water travel between this area and the settlement will become hazardous in places and impossible in others. Hence it will be necessary to provide alternate overland trails to the area of safe ice. It is not known to what extent the diversion of flow will alter the domestic winter fishery and its associated transportation demands.

Commercial Winter Fishery: The reduced current velocities due to increased lake level and reduced volume of winter flow in Regions 2 east, 3 and 4 will significantly improve the condition of the ice in this area.

For example, the condition of the weak ice cover south of the Long Portage in Region 2 east and opposite the east end of Long Point will likely become safe for bombardier travel. Similarly decreased current velocities due to increased lake levels may be expected to improve the ice conditions from the long bay west of the Settlement to the fish packing plant near Leaf Rapids. However, that portion of the winter route now passing through the Settlement will have to be abandoned and replaced by an overland route crossing the Narrows by means of a bridge in the Settlement or crossing the diversion route in South Bay. Alternately the route could bypass the Settlement to the north by going west from Camp 7 to the old Lynn Lake Portage, then south past Camp 3 and then west to Leaf Rapids.

As noted earlier, the Churchill River water contributes a very small portion of the total heat gain during the spring break-up period. Hence the diversion of flow is not expected to affect the time or duration of the spring break-up period in the commercial winter fishery area. Similarly the time and duration of the fall freeze-up period in this area is likely to be little affected, except that areas of marginal ice under existing conditions will likely develop a better ice cover more quickly.

Fur Trap Lines: Changes in winter ice cover as they affect trap line activity will be minor. As noted earlier, the fall and spring trapping seasons span the freeze-up and break-up periods respectively. Hence, trappers have to contend with poor ice conditions and minor changes in condition are of no consequence. The greatly changed ice conditions in the area of the Settlement may have a secondary effect on the trapping activity.

Mitigation Measures

The loss of the existing safe winter ice cover in the Narrows at the Settlement will have a major impact on the community. Possible mitigation measures include:

1. One major crossing suitable for heavy trucks.
2. One or two additional crossings suitable for bombardiers.
3. Construction of overland trails (initially for winter use only) along each side of the Narrows.
4. Construction of an overland trail to Lamb's Portage to provide access to the winter fisheries.

Accuracy of Ice Cover Estimates

The state of the art of estimating the condition of ice covers is such that there is a broad range of current velocities over which it is not possible to predict the quality of the ice cover with confidence. Moreover, the quality of the ice cover varies from one year to the next, improving with lower temperatures and deteriorating with thicker snow cover and increased velocities of flow.

Some indication of the accuracy of ice cover predictions may be obtained by observing that the Manitoba Hydro analysis indicates a safe ice cover crossing (with ice up to 2 feet thick) will probably form in the Narrows area and that normal ice cover will prevail some 2000 feet upstream and down stream of the open-water shown. The relationships contained in Table VIII which are based on the data of Table VI on the other hand, would indicate that an ice crossing safe for bombardiers (say 8 inches of ice) is not to be expected for a distance of 4 miles south of the proposed town centre site. The latter prediction may be overly pessimistic but cannot be ruled out entirely.

It is also to be noted that the build-up of the ice cover, under marginal conditions is a gradual uncertain process and that the time from the first appearance of ice along the shoreline until the time of development of a safe crossing may require the larger part of the winter season, particularly if snowfall is heavy. It may then be necessary to operate for extended periods under partial ice cover conditions using bridges or ferries. In this case the development of a safe ice crossing for a short period is of no great advantage.

OBSERVATION AND CONCLUSIONS

South Indian Lake Settlement

The life style of the Settlement requires the capacity to cross the Narrows at least on foot or by canoe on a daily basis. The future development pattern will increase the demand for such crossings.

The existing ice regime largely meets the existing demand for crossings except that significant interruptions to transportation of school children occur.

It is anticipated that the ice cover in the Narrows under diversion conditions will be greatly altered. It is probable that there will only be one area in the Narrows safe for a bombardier crossing. Furthermore a safe ice cover may develop much later than at present. The present practise of travelling on the ice along the Narrows will also no longer be possible.

Mitigation measures may have to include at least one bridge or ferry crossing - at least until experience under diversion conditions indicates otherwise - and a series of overland trails parallel to the shoreline for winter travel.

Domestic Winter Fishery

The domestic winter fishery requires power-toboggan and bombardier travel from the Settlement to an area some 4 to 6 miles to the north.

The existing ice regime largely meets the existing transportation demands of the domestic winter fishery.

Under diversion conditions modest improvement in the ice conditions in the area of the fishery is anticipated. However, it will no longer be possible to travel to the fishery on the ice in the Narrows.

Overland trails on either side of the Narrows leading to the area of the fishery will be required.

Commercial Winter Fishery

The commercial winter fishery requires random bombardier travel over the Lake north of latitude57°N to collect fish. It also requires bombardier travel south to the Settlement and then west to Leaf Rapids.

The existing ice regime is largely adequate to meet the existing transportation demands, although some overland portages and caution in the use of the ice cover is required.

Under diversion conditions a significant improvement in the ice conditions in the area of the fishery and along the routes from the fishery to the Settlement and to Leaf Rapids is anticipated. However those portions of the routes in the vicinity of the Settlement will become unsafe for use and alternate means of crossing (or avoiding) the Narrows will have to be provided.

Fur Trap Lines

The Transportation demands of the fur trapping industry do not appear to be severe. They are apparently, adequately met by the existing ice regime. Future changes in the ice regime are not expected to have significant impact on the fur trapping industry except for the local disruption of transportation in the Settlement.

REFERENCES

1. Water Resources Branch Report, " Water Levels and Discharge Information - Southern Indian Lake and the Rat-Burntwood Diversion Route" by L. Leung, prepared for the Lake Winnipeg, Churchill and Nelson Rivers Study Board.

2. Environment Canada, Fisheries Service Report,"Hydrography of Southern Indian Lake: Present Conditions and Implications for Hydro-Electric Development" by T.R. Cleugh prepared for the Lake Winnipeg,Churchill and Nelson Rivers Study Board.

3. Environment Canada, Fisheries Service Report,"Morphometry of Southern Indian Lake: Present Conditions and Implications of Hydro-Electric Development" by T.R. Cleugh, H. Ayles and W. Baxter, prepared for the Lake Winnipeg, Churchill and Nelson Rivers Study Board.

TABLE I

SOUTH INDIAN LAKE SETTLEMENT

INTERRUPTION OF OVER-WATER TRANSPORTATION

Type of Transportation	Interruption
from boat to walking	1 - 3 days
from boat to power toboggan	1 week
from boat to bombardier	2 - 3 weeks
from boat to heavy truck and trailer	2 - 3 months

TABLE II

SOUTH INDIAN LAKE SCHOOL

SCHOOL BUS RECORD

Year	Bombardier	Boat	Bombardier
1972	to Friday, May 5	from Wednesday, May 24 to Monday, October 16	from Friday, November 3
1973	to Friday, May 4	from Monday, May 28 to Friday, November 2	from Monday, November 12

TABLE III

SOUTH INDIAN LAKE SCHOOL

ATTENDANCE OF SELECTED STUDENTS

WHO NEED TO CROSS NARROWS TO REACH SCHOOL

AND WHO ARE CONSIDERED TO HAVE GOOD ATTENDANCE

Year	Name and Grade		Day of Month Absent			
			October	November	April	May
1972/73	Gordon	8	4, 6, 11, 16, 17, 18	6	none	all
	Ernest	8	16, 17, 18	1, 6, 7, 8, 9, 10, 17	16	7, 8, 9, 14, 15, 16, 24, 25
	Randal	2	6, 16, 17, 18	28	30	3, 28
1971/72	Gordon	7	18, 29	1, 2, 3, 4, 5	none	9, 11, 23
	Ernest	7	28	none	none	1, 8, 11, 18, 19, 23
	Randal	1	27, 28, 29	1, 2, 3, 4, 5	10, 17, 20, 24, 25, 26, 27, 28	all
	John	7	8, 25		4, 5, 6, 7, 10, 11, 26	4, 5
1970/71	Gordon	6	all	all	none	5, 6, 7, 10, 11, 12, 13, 14, 19, 28
	Ernest	6	2, 7, 8	5, 6	1, 2, 8, 26, 30	28
	John	6	2, 7	none	9, 19, 20, 21	28

TABLE IV

SOUTH INDIAN LAKE SCHOOL

GRADE I ATTENDANCE

		1972	1971	1970	1969	1968
October	15	S	15	23	14	S
	16	11	S	22	20	14
	17	9	S	S	20	13
	18	10	16	S	S	14
	19	13	16	20	S	15
	20	15	17	21	18	S
	21	S	16	21	9	S
	22	S	16	20	10	16
	23	18	S	20	17	12
	24	18	S	S	19	16
	25	19	16	S	S	16
	26	16	15	19	S	16
	27	18	14	20	22	S
	28	S	7	19	22	S
	29	S	5	20	22	17
	30	22	S	21	24	17
	31	21	S	S	24	15
November	1	15	4	S	S	17
	2	20	6	20	S	16
	3	20	7	20	20	S
	4	S	8	22	22	S
	5	S	7	16	20	7
	6	18	S	14	22	7
	7	20	S	S	21	8
	8	20	16	S	S	9
	9	22	17	12	S	14
	10	22	16	12	23	S
	11			Rembrance Day		
	12	S	15	16	24	19
	13	22	S	17	24	18
	14	22	S	9	23	18
	15	22	15	S	S	18

NOTE: Attendance is fairly regular till about May when attendance drops to about 50% and then recovers to about 60% in June.

TABLE V

SOUTHERN INDIAN LAKE

WATER TEMPERATURE (^{o}C) AT BEGINNING OF MONTH

	Month											
Region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
09	0	0	0	0	2(?)	7	15	17	15	6	2(?)	1(?)
10	.3	.3	.3	.3	.3	10	13	16	16	4	.3	.3
20	.5	.5	.5	.5	.5	4	13	16	16	4	.5	.5
30	.7	.7	.7	.7		4	11	15	16	6	.7	.7
40	.8	.8	.8		.8	2	11	16	16	6	.8	.8
50	1	.4	.2	1(?)	2(?)	3	10	15	16	6	1	1
60	2	2	2	2	2	7	15	16	16	5	2.5	2

NOTE: Temperatures are mean temperature over mean depth of water in region from Reference 2.

TABLE VI

FLOW AND ICE CONDITIONS UNDER

NATURAL CONDITIONS

Cross-Section	Water Level	Area (sq. ft.)	Top Width (ft.)	Flow (c.f.s.)	Velocity (ft./sec.)	Ice Conditions for Bombardier
1	850	23,000	530	30,000	1.3	open-water
2	849.5	33,000	920	30,000	0.91	open leads
3	848	12,000	400	30,000	2.5	open
4	848	133,000	2,950	30,000	0.22	closed
5	848	26,000	1,230	30,000	1.2	open
6		66,000(?)	1,800	30,000	0.45	closed
7		123,000(?)	5,300	30,000	0.24	closed
8		13,000(?)	900	30,000	2.3	open
9	837	75,000(?)	3,100	30,000	0.40	open leads
10	837	161,000	7,500	30,000	0.19	closed, unsafe
11	837	198,000	10,800	30,000	0.15	closed, marginal
12	837	332,000	19,000	30,000	0.09	closed, safe
13	837	130,000	7,200	30,000	0.23	closed, marginal
14	837	276,000	7,200	30,000	0.11	closed, unsafe
15	837	10,500	630	1,500(?) 200	0.14 0.02	closed, unsafe
16	837	10,500	480	1,500(?) 200	0.14 0.02	closed, marginal
17	837	70,000(?)	4,200	1,500(?) 200	0.02 0.003	closed, safe

TABLE VII

FLOW AND ICE CONDITIONS UNDER DIVERSION CONDITIONS

Cross-Section	Water Level	Area (sq. ft.)	Top Width (ft.)	Flow (c.f.s.)	Velocity (ft./sec.)	Ice Conditions for Bombardier
1				30,000		open water
2				30,000		open leads
3				30,000		open
4				30,000		closed
5				30,000		open
6				30,000		closed
7				30,000		closed
8				30,000		open
9	847	107,000(?)	3,300	30,000	0.28	closed, unsafe
10	847	238,000	7,900	30,000	0.12	closed, marginal
11	847	308,000	11,200	1,500	0.005	safe
12	847	522,000	19,200	1,500	0.003	safe
13	847	203,000	7,400	1,500	0.007	safe
14	847	348,000	7,200	1,500	0.004	safe
15	847	17,100	690	30,000	1.8	open
16	847	16,000	540	30,000	1.9	open
17	847	112,600(?)	4,260	30,000	0.27	closed, unsafe

TABLE VIII

EFFECT OF WATER CURRENT VELOCITY

ON CONDITION OF ICE COVER

Velocity	Ice Cover
0 - 0.1 ft./sec.	safe for bombardier
0.1 - 0.2 ft./sec.	marginal for bombardier
0.2 - 0.5 ft./sec.	unsafe for bombardier
0.5 - 1.0 ft./sec.	open leads
1.0 - ft./sec.	open water

Photo 2 - South Indian Lake Settlement. Hudson Bay Company Post and Nursing Station in foreground, proposed Town Centre in upper right. Note: transportation routes crossing Narrows. January 23, 1974

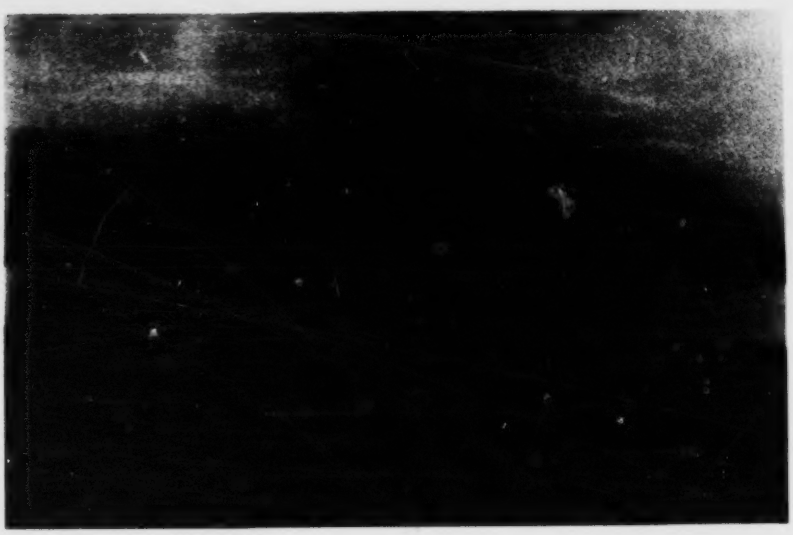


Photo 8 - Channel east of Long Point. Frozen in January, 1974. Cross-Section 14. January 23, 1974.

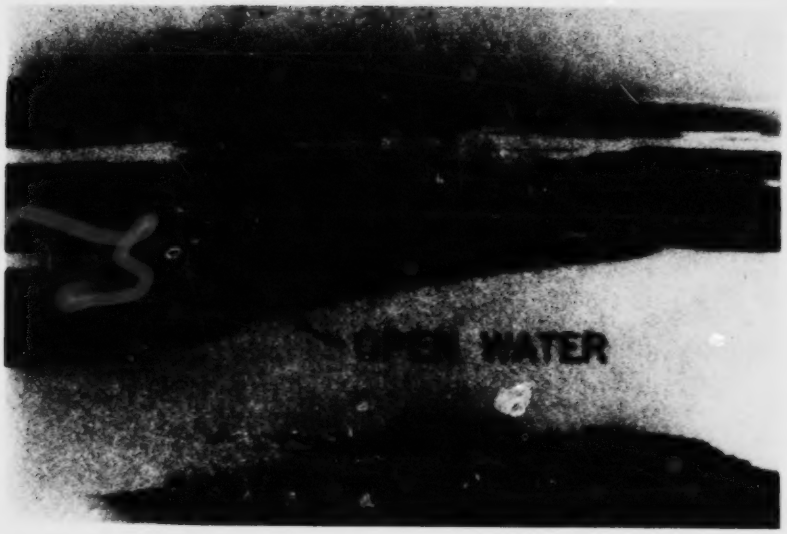


Photo 13 - Open Water in vicinity of North Channel at Missi Falls, January 23, 1974

Photo A - "Hole-on-Wall" area, facing west. Note: open water leads in middle channel, Cross-Section 9, March 1, 1973.

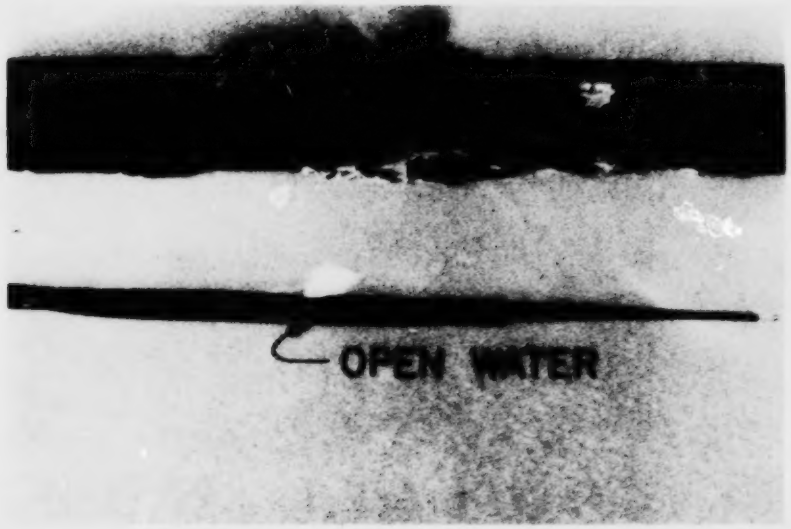
Photo B - "Hole-on-Wall", Close-up of open water in middle channel.
March 1, 1973

Photo C - "Hole-on-Wall", Close-up of open water in north channel.
March 1, 1973.

Photo 25 - Opachuanau Rapids,
Cross-Sections 7 and 8
Facing West
January 23, 1974

Photo 31 - Inlet to Lake Opachuanau, Cross-Section 6, Facing west
January 23, 1974

Photo 32 - Churchill River
January 23, 1974



Open water leads, Leaf Rapids Fish Packing Plant in upper photo
January 23, 1974

Photo 34 - Churchill River at Leaf Rapids. North Channel at Cross-Section 5
January 23, 1974

Photo 35 - Churchill River at Leaf Rapids; Cross-Section 3 at bridge; Cross-Section 4 in upper left; Cross-Section 5 south channel in centre.
January 23, 1974

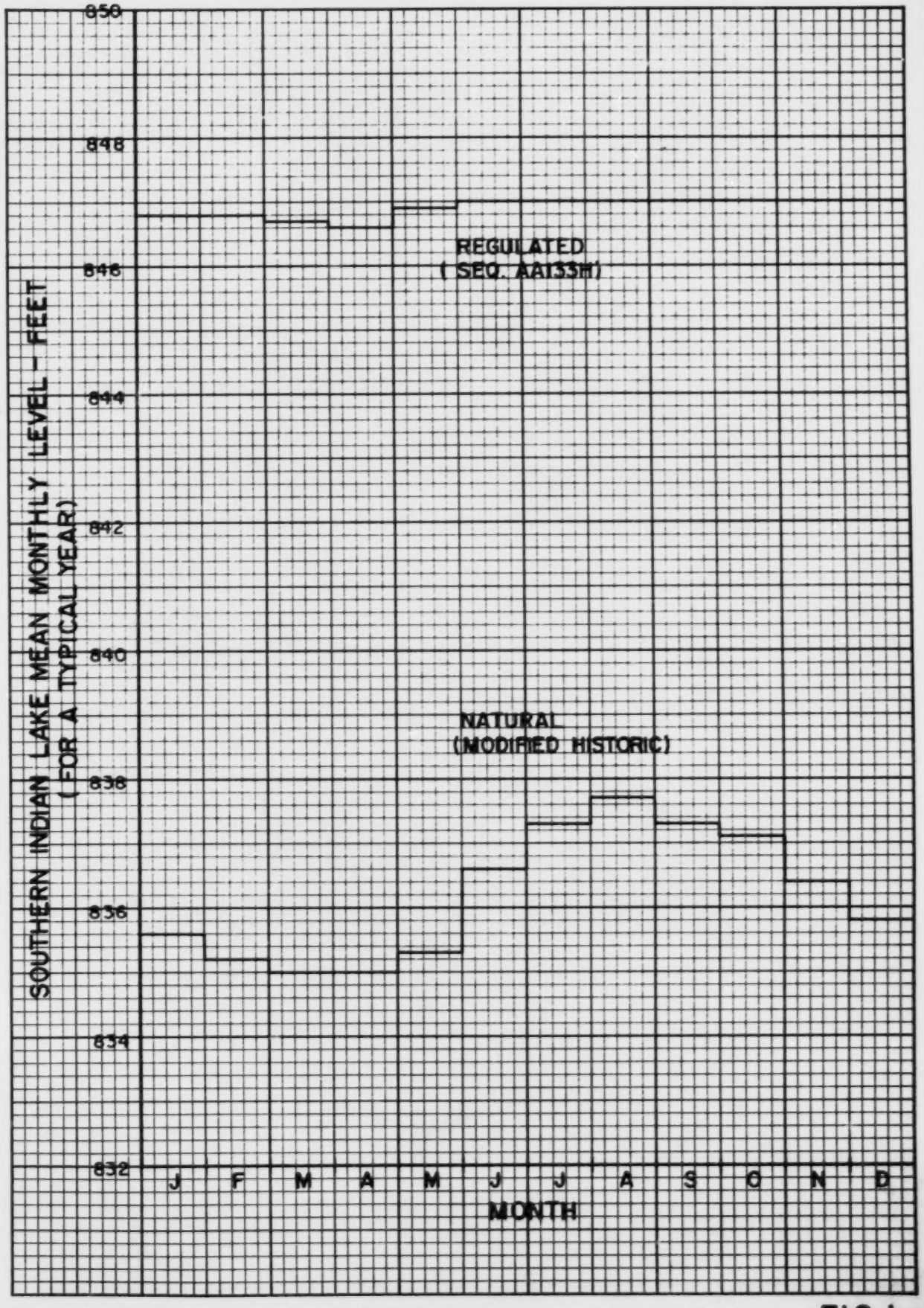

SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL – FEET
(FOR A TYPICAL YEAR)
850
848
846
844
842
840
838
836
834
832
REGULATED
(SEQ. AA133H)
NATURAL
(MODIFIED HISTORIC)
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

FIG. 1

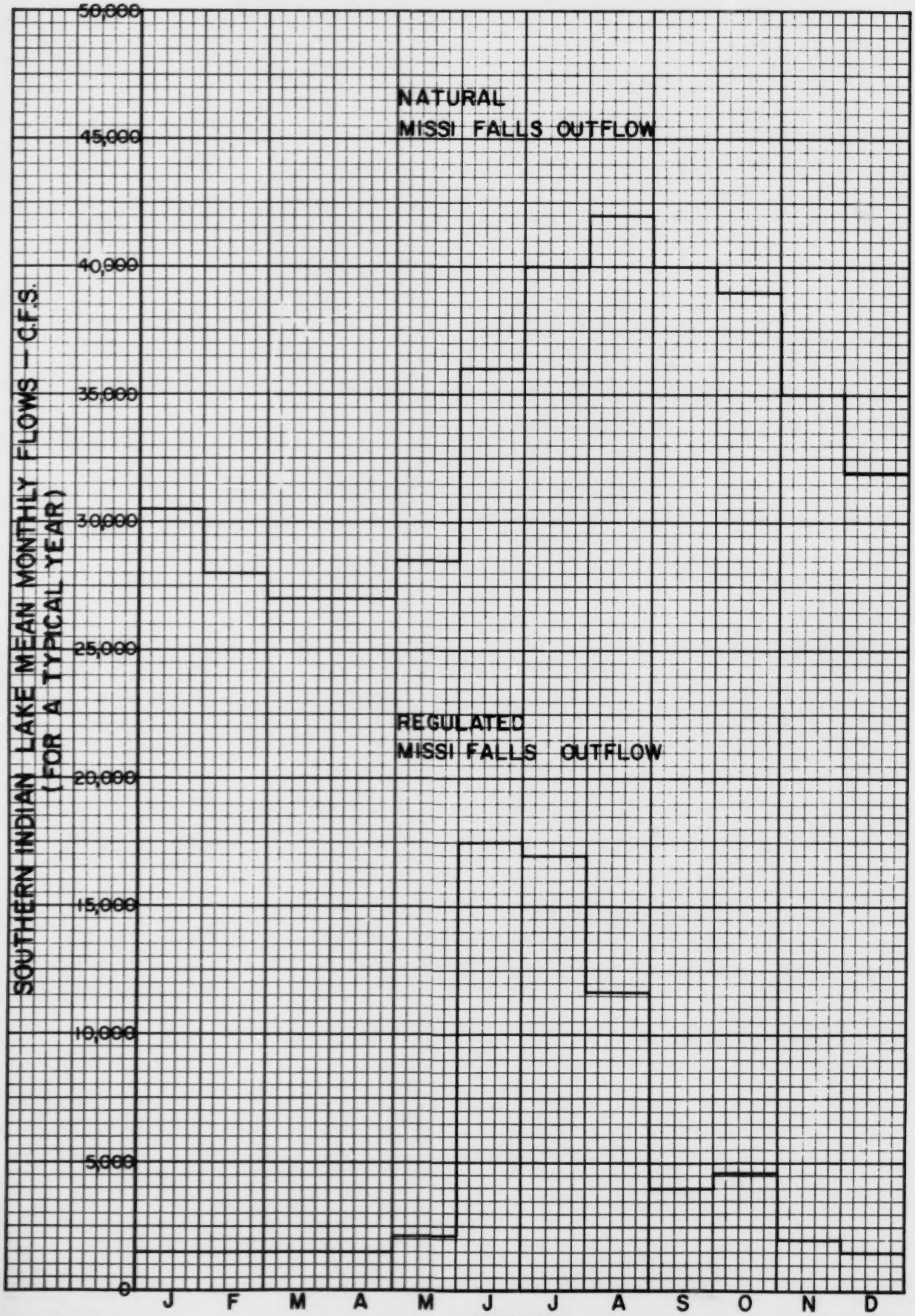

50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
NATURAL
MISSI FALLS OUTFLOW
REGULATED
MISSI FALLS OUTFLOW
SOUTHERN INDIAN LAKE MEAN MONTHLY FLOWS — C.F.S.
(FOR A TYPICAL YEAR)
J F M A M J J A S O N D
MONTH

FIG. 2A

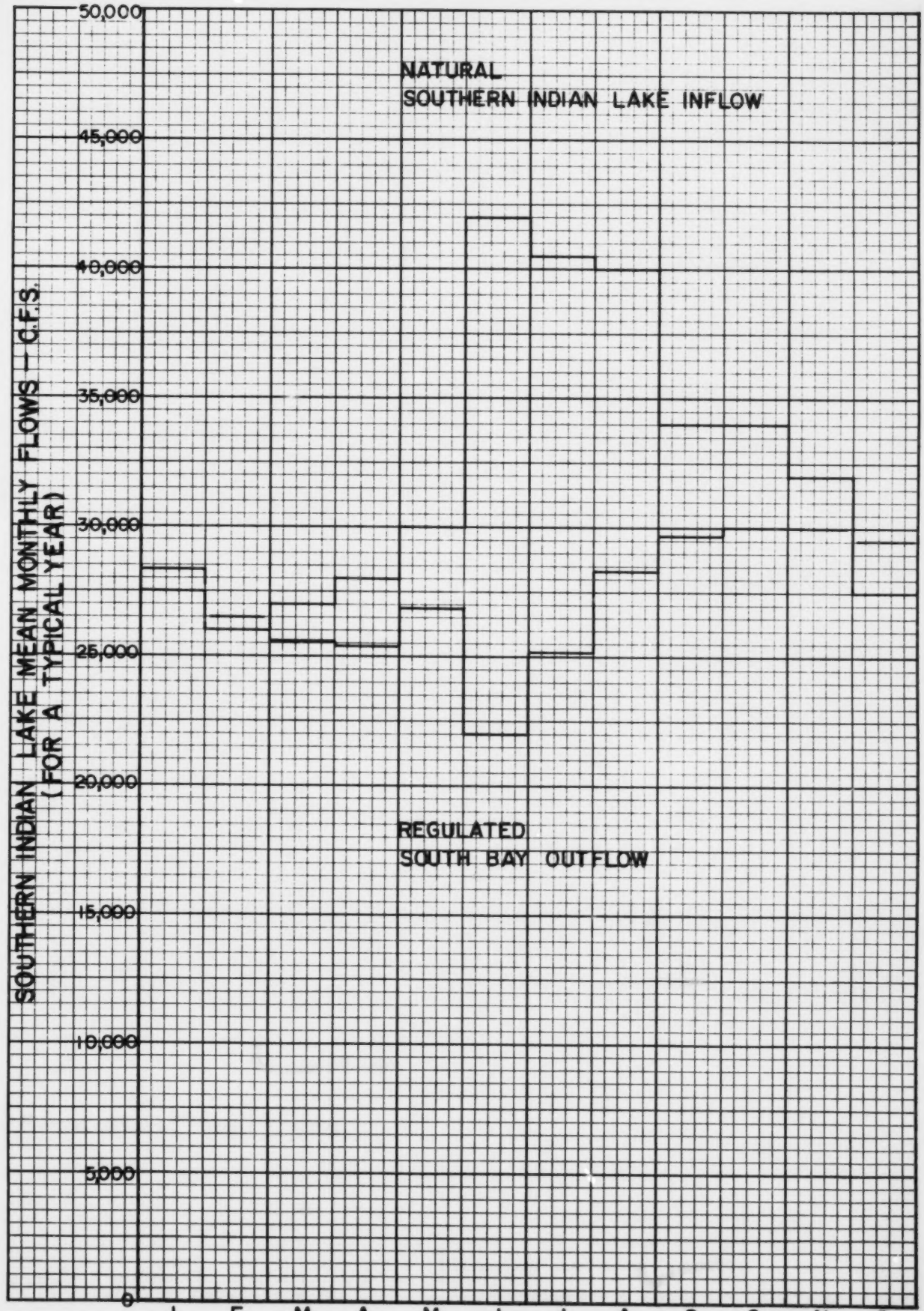
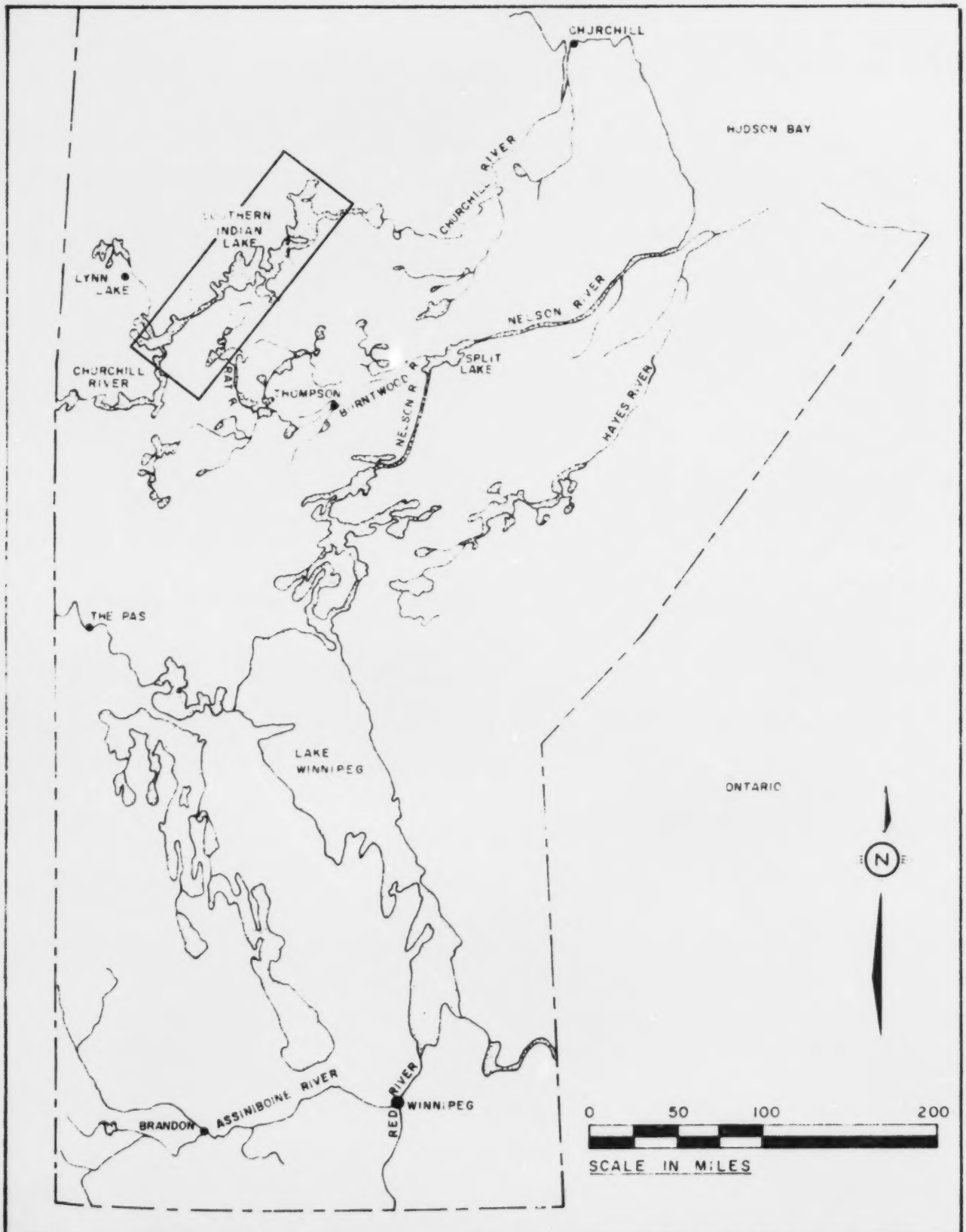

50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
SOUTHERN INDIAN LAKE MEAN MONTHLY FLOWS — C.F.S.
(FOR A TYPICAL YEAR)
NATURAL
SOUTHERN INDIAN LAKE INFLOW
REGULATED
SOUTH BAY OUTFLOW
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

FIG. 2B



PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

PREPARED	DRAWN A.S.U.	SUBMITTED	APPROVED
	CHECKED	DATE 21 FEB 74	DATE 21 FEB 74

CANADA - MANITOBA

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SOUTHERN INDIAN LAKE ICE COVER STUDY

KEY PLAN

SCALE	DATE	SHEET	FILE NO
AS SHOWN	FEB. 74	1 OF 1	61-6-1045

FIG: 3

391
FISH PACKING PLANT
CHURCHILL
32
391
1000
1000
1000
Karshuwigmak Lake
Pitchigaman Lake
RAT LAKE
500
500
500
1000

FISH PACKING PLANT

391

33

CHURCHILL

32

RIVER

31

6

7

8

28

LIMITS OF COMMERCIAL WINTER FISERY

LYNN LAKE

ROAD

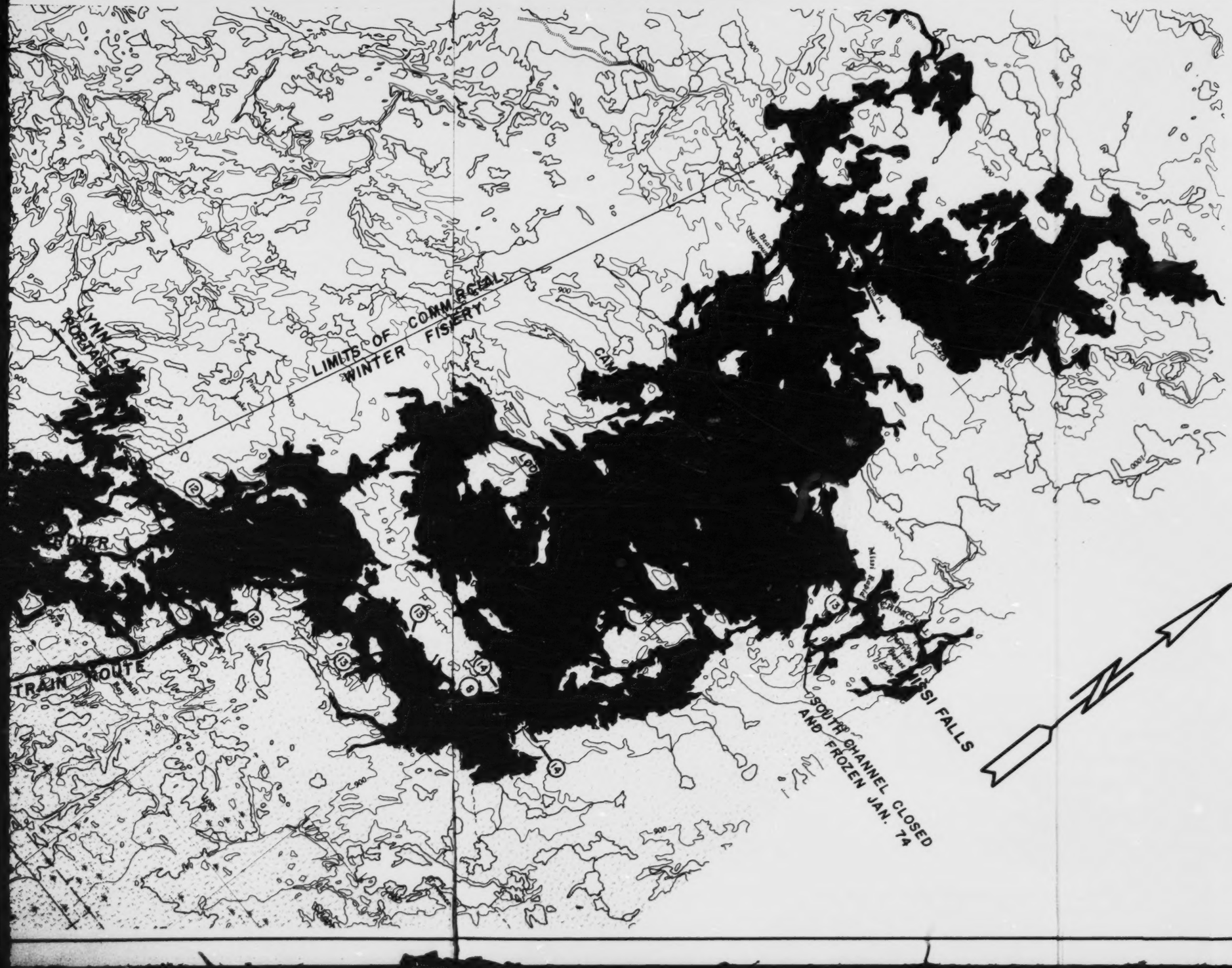
SILLEAF RAPIDS TO SOUTH BAY

SOUTH BAY CHANNEL

LAMB'S PORTAGE

TRACTOR TRAIN ROUTE

BEDIER



LEGEND

CROSS - SECTION (9)

PHOTO LOCATION (8)

OPEN WATER

NOTE : UNSAFE AND MARGINAL I
TRAVEL. ONLY MAIN AREA
ICE CONDITION REFERS T

0 5 10

SCALE IN MILES

PROVINCE OF MANITOBA

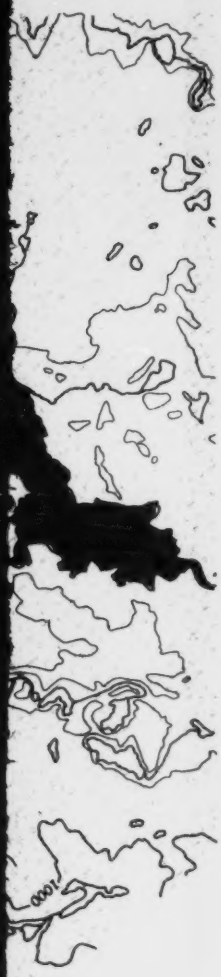
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

PREPARED | DRAWN A.S.U. | SUBMITTED | APPROVED | DATE | CHECKED | DATE

LAKE WINNIPE

SOU



LEGEND

CROSS - SECTION (9)— — — —(9)

PHOTO LOCATION (8) (A)

OPEN WATER

NOTE : UNSAFE AND MARGINAL ICE REFER TO BOMBARDIER TRAVEL. ONLY MAIN AREAS ARE SHOWN.
ICE CONDITION REFERS TO EXISTING CONDITION.

0 5 10 15

SCALE IN MILES

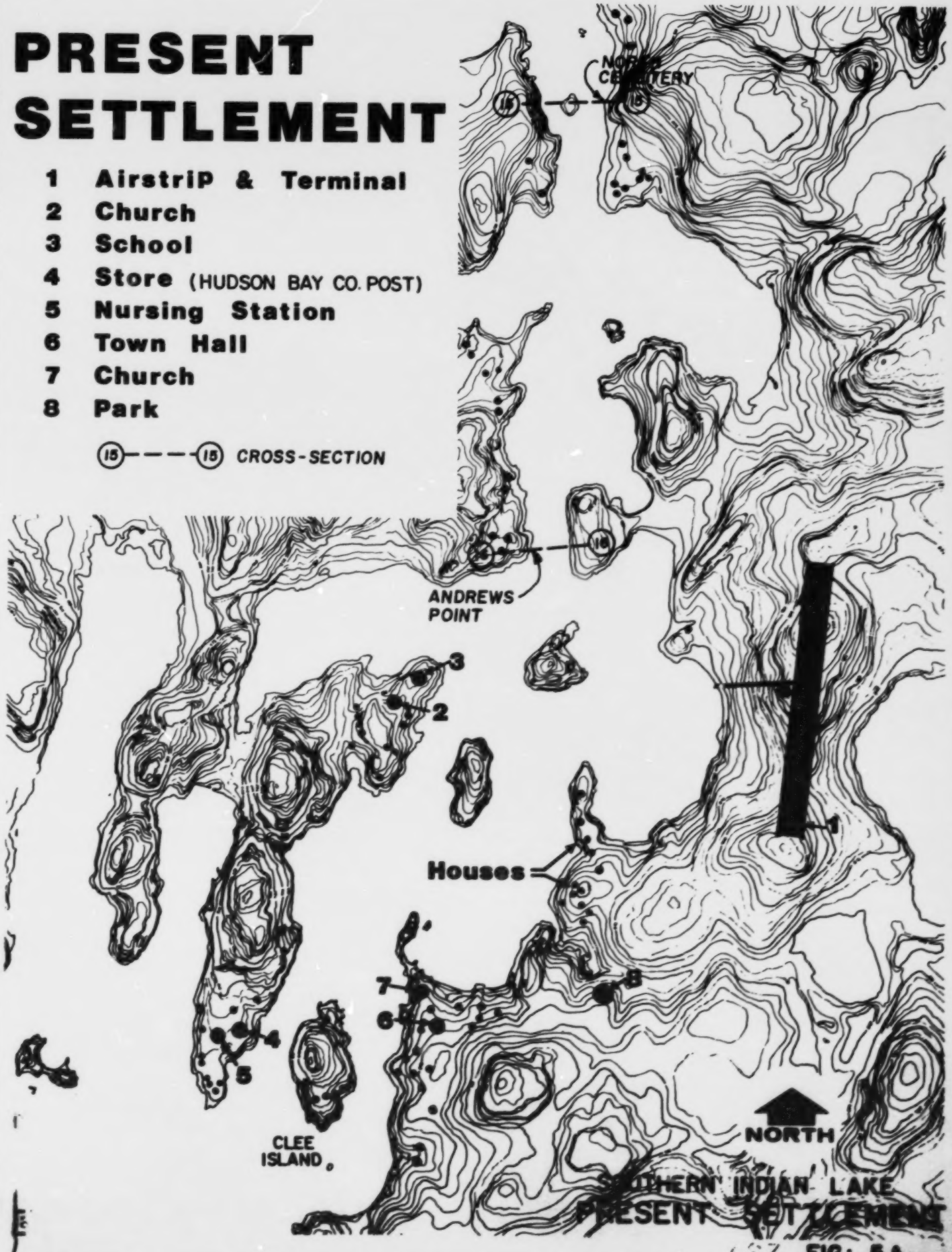
PROVINCE OF MANITOBA DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT WATER RESOURCES BRANCH	CANADA - MANITOBA LAKE WINNIPEG CHURCHILL AND NELSON RIVERS STUDY BOARD SOUTHERN INDIAN LAKE ICE COVER STUDY PLAN OF LAKE
PREPARED · DRAWN A.S.U. · SUBMITTED · APPROVED · CHECKED · DATE · DATE	SCALE AS SHOWN · DATE FEB. 74 · SHEET 1 OF 1 · FILE NO. 61-6-1046

FIG: 4

PRESENT SETTLEMENT

1 Airstrip & Terminal
2 Church
3 School
4 Store (HUDSON BAY CO. POST)
5 Nursing Station
6 Town Hall
7 Church
8 Park

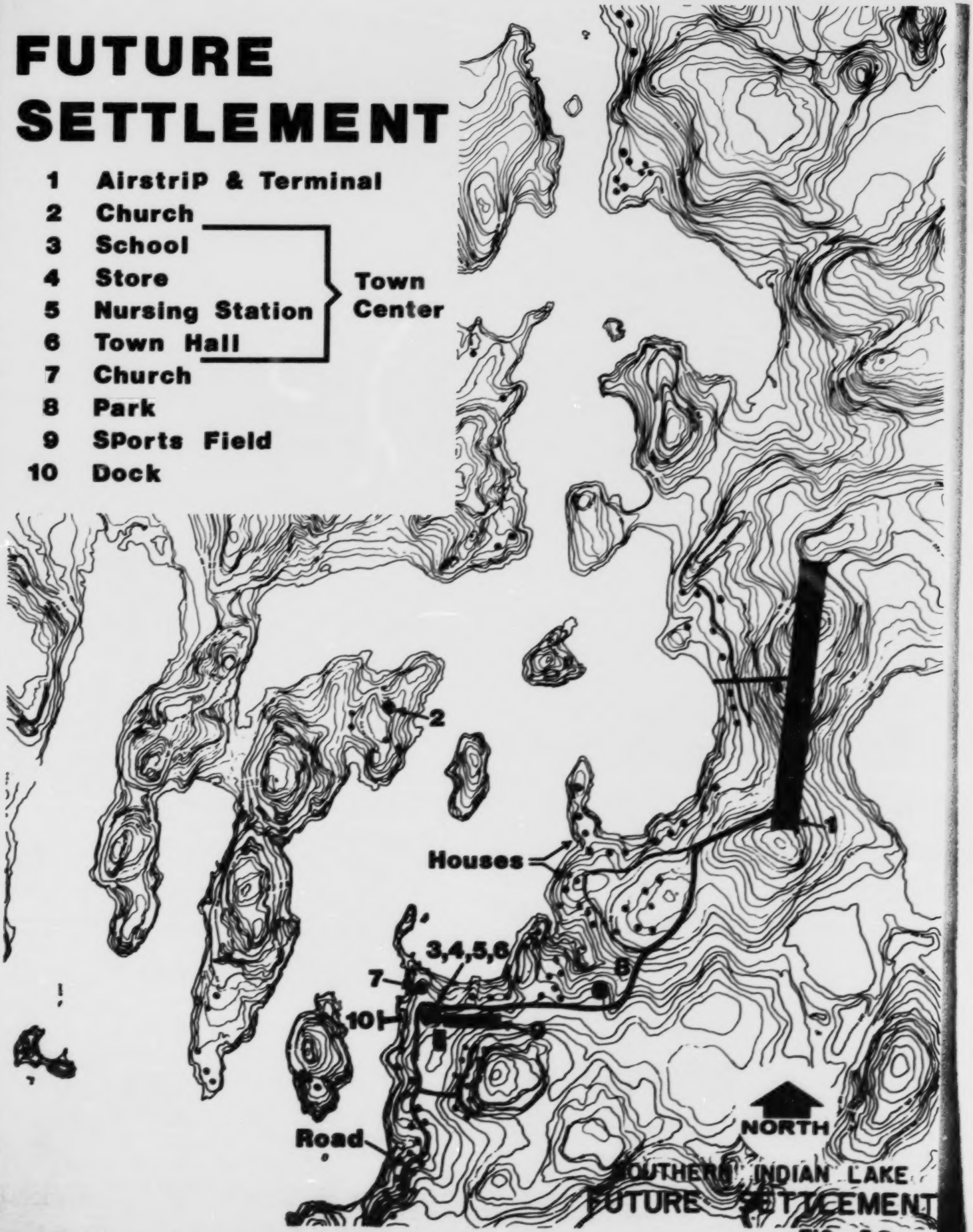
(15)---(15) CROSS-SECTION



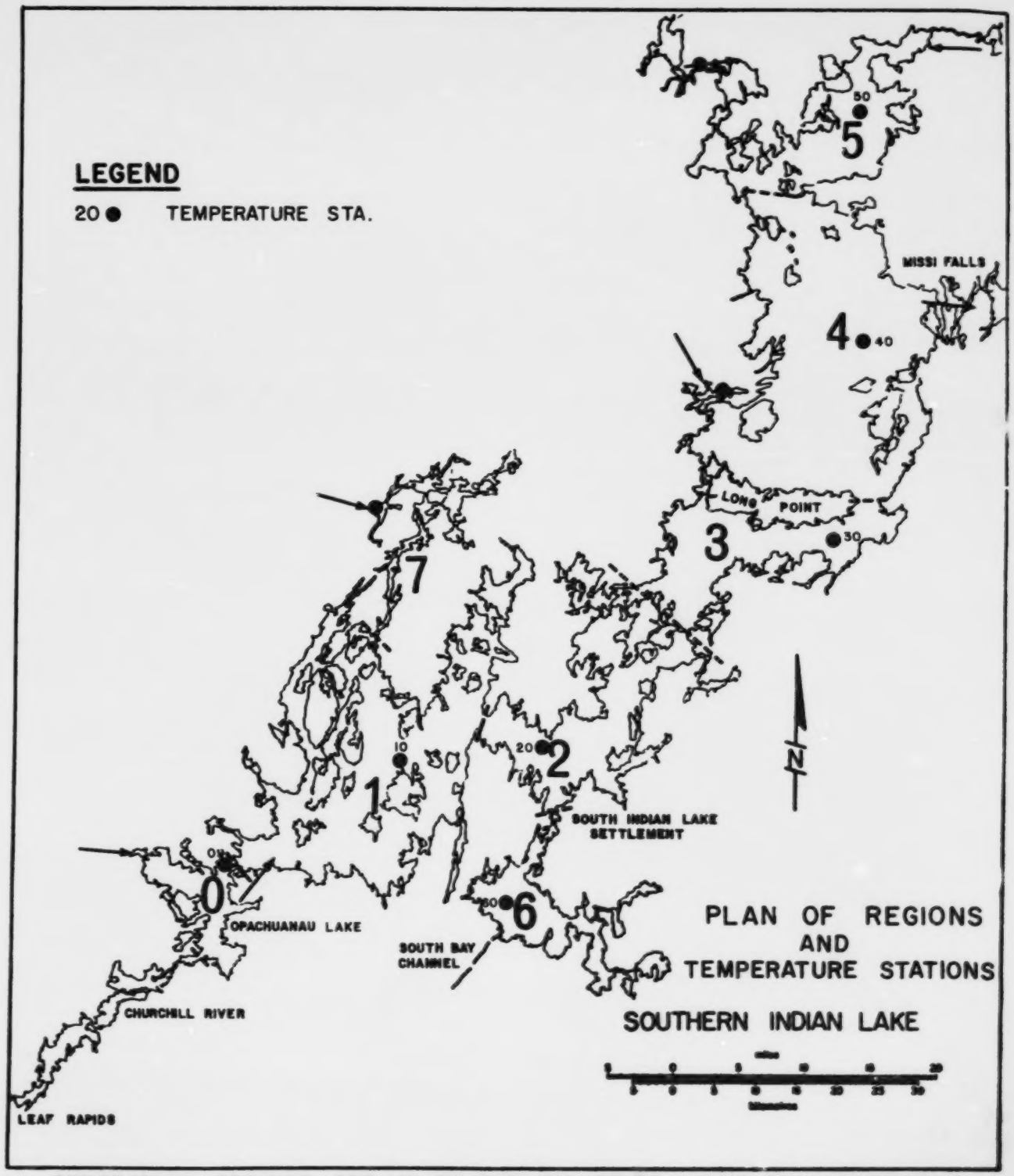
SOUTHERN INDIAN LAKE
PRESENT SETTLEMENT
FIG: 5A

FUTURE SETTLEMENT

1 AirstriP & Terminal
2 Church
3 School
4 Store
5 Nursing Station
6 Town Hall
Town Center
7 Church
8 Park
9 SPorts Field
10 Dock



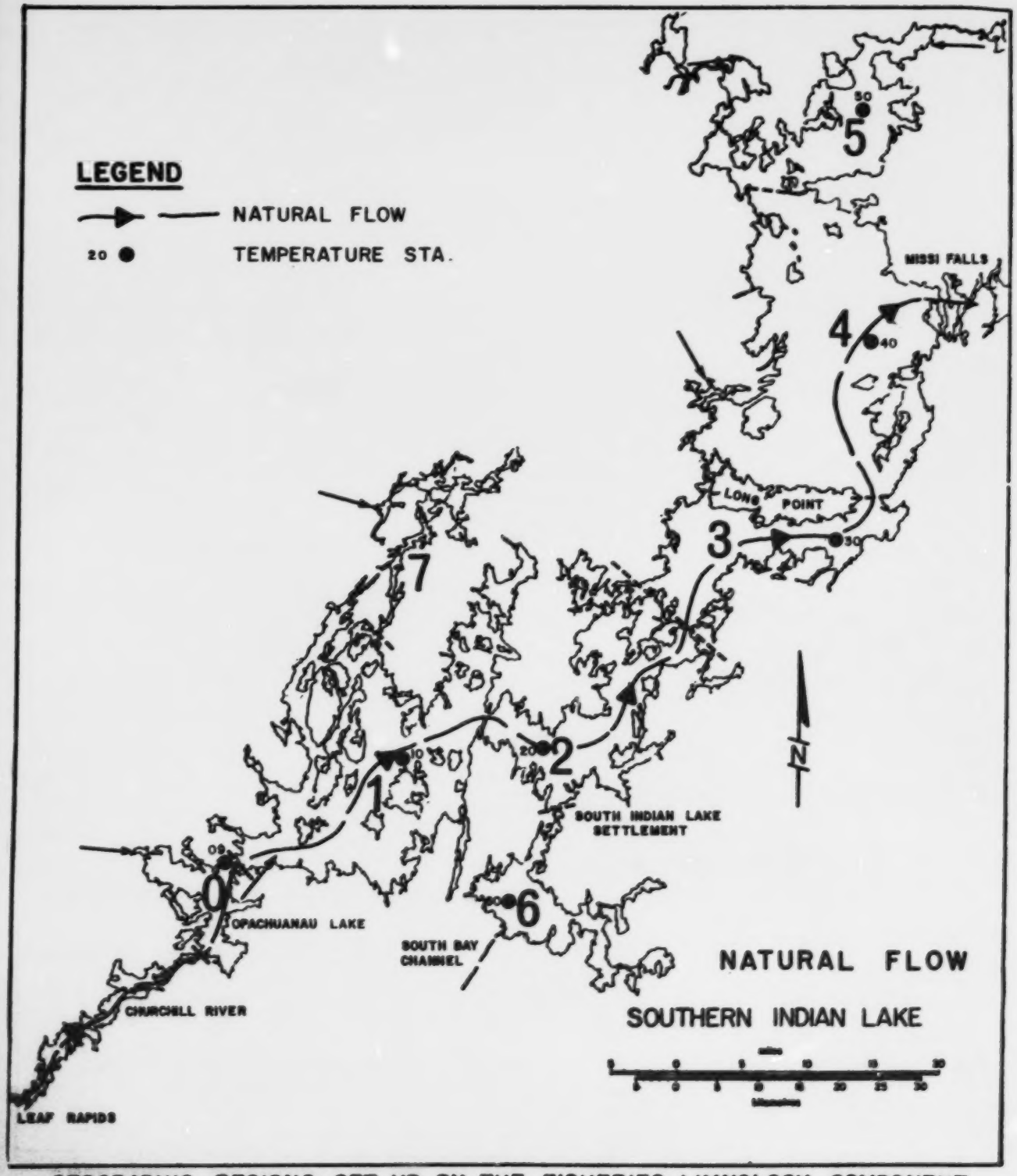
SOUTHERN INDIAN LAKE
FUTURE SETTLEMENT
FIG: 5B



GEOGRAPHIC REGIONS SET UP BY THE FISHERIES LIMNOLOGY COMPONENT

FIG: 6

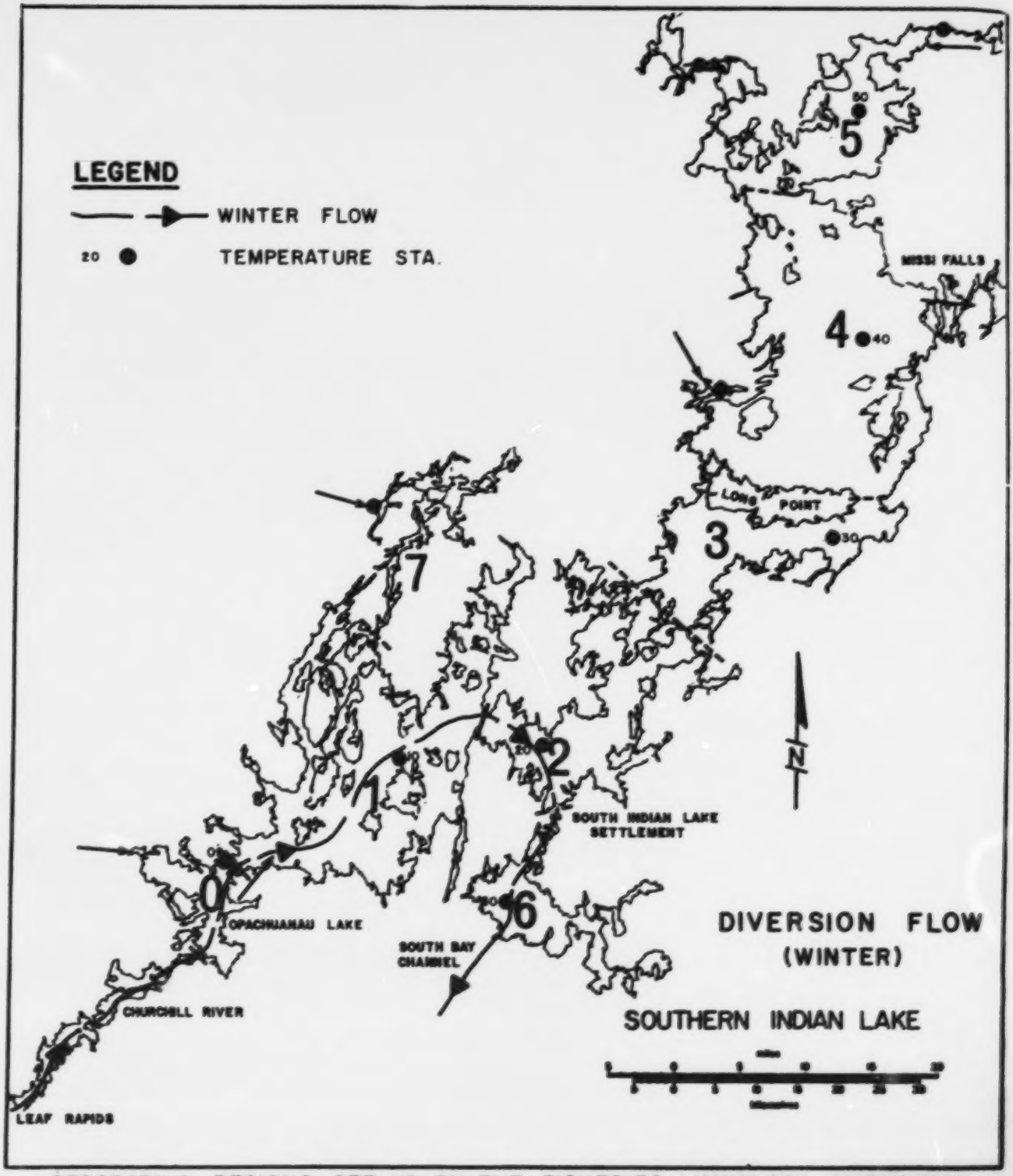
(note: arrows indicate direction of flow of major streams)



GEOGRAPHIC REGIONS SET UP BY THE FISHERIES LIMNOLOGY COMPONENT

FIG: 7

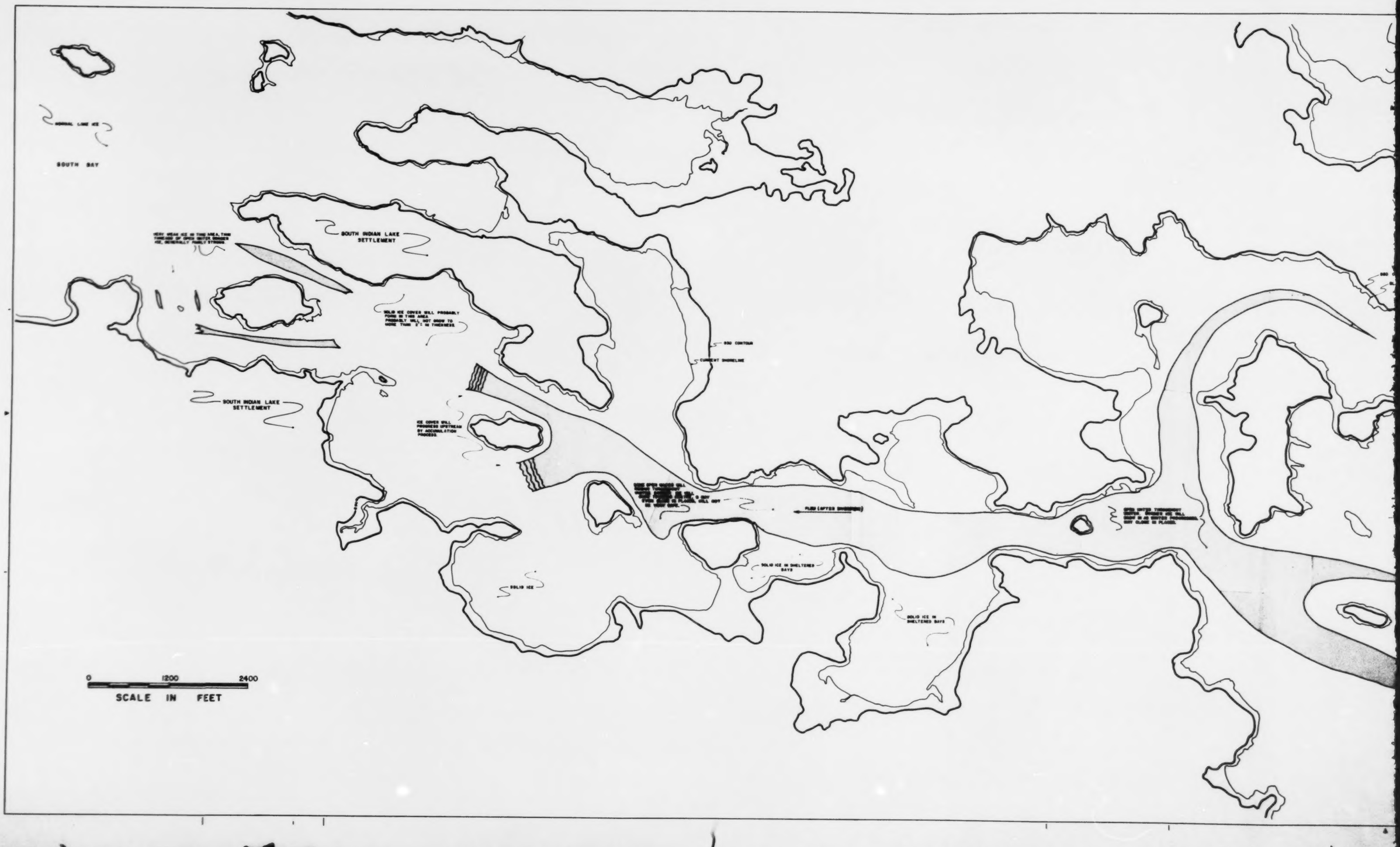
(note: arrows indicate direction of flow of major streams)



GEOGRAPHIC REGIONS SET UP BY THE FISHERIES LIMNOLOGY COMPONENT

FIG: 8

(note: arrows indicate direction of flow of major streams)


SOUTH BAY
SOUTH INDIAN LAKE SETTLEMENT
SOUTH INDIAN LAKE SETTLEMENT
SOUTH INDIAN LAKE SETTLEMENT
930 CONTOUR
CURRENT SHORELINE
SOLID ICE
SOLID ICE IN SHELTERED BAYS
SOLID ICE IN SHELTERED BAYS
0
1200
2400
SCALE IN FEET

NOTES

1. THIS IS A VERY BASIC ASSESSMENT. IT IS PROBABLY ADEQUATE FOR QUALITATIVE USE.
2. FREEZE OVER WILL BE A COMPLETELY DIFFERENT PROCESS FROM PRESENT. FREEZE OVER WILL OCCUR VERY GRADUALLY. IT WILL BE GENERALLY LATER THAN PRESENT, AND SOME AREAS WILL NOT FREEZE OVER, AS NOTED.
3. BREAKUP WILL BE QUITE SUDDEN. LARGE AMOUNTS OF FLOATING ICE WILL PASS THROUGH THE NARROWS, BUT NO ICE JAMS WILL OCCUR.
4. WATER WILL BE GENERALLY 1 - 2°C COLDER THAN PRESENT. WINTER TEMPERATURES WILL BE ABOUT 32 4°F. UNIFORM THROUGHOUT DEPTH EXCEPT FOR TYP 2 OR 3 FEET.

SOUTHERN INDIAN LAKE

950 CONTOUR
EL. 950 (APPROX PRESENT SHORELINE)

950 CONTOUR
CURRENT SHORELINE

FLOW (AFTER DIVERSION)

ICE COVER IN THIS SINGLE AREA WILL BE WEAK, POSSIBLY WILL HAVE LEADS OF OPEN WATER.

SOLID ICE

SOLID ICE IN SHELTERED BAYS

SOLID ICE IN SHELTERED BAYS

MANITOBA HYDRO
CHURCHILL RIVER DIVERSION
SOUTH INDIAN LAKE SETTLEMENT
PROBABLE ICE PATTERNS
AFTER DIVERSION
JUNE 30, 1972
61-6-1047

FIG: 9

APPENDIX 2 - VOL. 1 - G

POST-DIVERSION ICE REGINE STUDY
OF THE LOWER CHURCHILL RIVER

POST-DIVERSION ICE REGIME STUDY OF THE LOWER CHURCHILL RIVER

by

R. HAUSSER and S. ALAM
LaSalle Hydraulic Laboratory Ltd
LaSalle, Quebec
May, 1974

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

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1. SYNOPSIS

The purpose of the present study was to assess the post-diversion ice regime of the Churchill River between Missi Falls and the estuary, with emphasis on the lower reach of the river downstream of Little Churchill River.

Computation of ice cover formation and accumulation for three river discharges of 35,000 cfs, 10,000 cfs and 4,000 cfs were carried out and these lead to the following conclusions and recommendations:

a) Under average post-diversion discharge conditions the river flow would be maintained throughout the winter. However, to assure an early winter stable cover formation and sufficient river flow in the downstream reach, a minimum discharge of 4,000 cfs should be released at Missi Falls or at the outlet of Billard Lake at least until the 15th of December. Under extreme minimum discharge of 1,500 cfs at Missi Falls it is anticipated that major part of the flow section in the river downstream would be frozen fast. Only a small discharge about 100 cfs would most probably reach downstream, flowing through the thalweg and loose ice blocks. Available field data was not sufficient to undertake an ice cover computation for this discharge.

b) Spring break-up conditions would maintain vegetation trim lines, some scoured along the shore in the lower reach of the river. These would, however, be lower than the existing ones.

c) Lowering of the water and ice cover levels would adversely affect the operation of the present water intake for the town of Churchill. Remedial measures such as construction of rockfill weirs at Section MH20 or a storage lake beside the town of Churchill are suggested.

d) There would be a considerable reduction in the volume of early winter ice inflow and formation in the port of Churchill. The complete cover formation in the harbour would be delayed, and would depend more on the sea freeze-up.

e) The 1,200 ft dyke proposed by the Churchill Development Board at the south end of the harbour would help to partially improve the flow conditions, but at the same time might create some new problems. It should therefore be studied further before its construction.

2. TERMS OF REFERENCE

By letter from Mr. D.G. Ramsey, Assistant Study Director of Lake Winnipeg, Churchill and Nelson Rivers Study Board (L.W.C.N.R.S.B.) to Mr. R. Hausser, Vice President and Technical Manager of LaSalle Hydraulic Laboratory Limited (LHL) dated December 8, 1973, Mr. Hausser was requested to examine and comment on a report by Dr. R.W. Newbury entitled: "The Effect of Diversion on the Winter Regime of the Abandoned Lower Churchill River". In particular, an evaluation of his conclusion that, "the flow during the early stage of icing may be decreased to zero for extended periods in midwinter" (page 23) was sought. Also LHL was asked to submit a proposal for a study to assess the new ice regime of the Churchill river from Missi Falls (the outlet of Southern Indian Lake and Location of Churchill River Diversion Control Structure) to the Churchill River estuary with emphasis on the lower reach of the river from the Little Churchill River to the estuary.

By letter of January 9, 1974 to Mr. D.G. Ramsey, Mr. Hausser gave his evaluation of Dr. R.W. Newbury's report.

On January 30, 1974 by a contract between LHL and the Province of Manitoba, authorization was given to carry out studies in accordance with the proposal submitted by LHL to L.W.C.N.R.S.B. on January 7, 1974.

3. INTRODUCTION AND PURPOSE OF THE STUDY

The proposed diversion of the Lower Churchill River at Southern Indian Lake (Figure 1) would affect the discharge, water levels and ice regime of the river below Missi Falls. The purpose of this study was to assess the post diversion ice regime of the Churchill River between Missi Falls and the estuary with emphasis on the lower reach of the river downstream of Little Churchill River. Brief examination was also made of the following annex problems:

a) The effect of the new regime on the water intake at Churchill.

b) The effect of reduced flow on the phenomenon of salt water penetration.

c) The effect of reduced flow on the Port of Churchill and in particular on the 1,200 ft breakwater dyke proposed by Churchill Development Board at the south end of the harbour as a measure to control slush ice.

d) The impact of diversion on the wildlife habitat.

The Lower Churchill River (Figure 1) from Missi Falls to Hudson Bay is about 275 miles (1,450,000 ft) long , of which the upper 100 miles is a series of lakes separated by short stretches of river. Over this 100 miles the river

drops by about 170 ft. From the outlet of Billard Lake to the confluence of Deer River it flows over a series of rapids with widely varying width and flow sections. The total drop over this 135 miles of the river is about 600 ft.

Considering the length of the river studied and the complexities of the problems involved on the one hand, and the limitations of the existing field data and a reporting dead-line of April 30, 1974 on the other hand, the nature of the study from the outset had to be rather general. However, the excellent co-operation we received from both the Study Office and Manitoba Hydro was very helpful and enabled us to conclude the study within the given time.

4. EFFECTS OF DIVERSION ON THE DISCHARGE

Studies carried out to date by the Manitoba Water Resources Branch and Manitoba Hydro have established the following pre-and post-diversion monthly discharges of the Lower Churchill River:

LOWER-CHURCHILL RIVER
PRE DIVERSION MONTHLY FLOWS

Average Mean Monthly Flows

	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Missi Falls	32164	29666	27906	27610	31037	38961	44143	44132	41861	38948	37105	34771
Local Inflow	1432	1217	1064	1170	8491	10817	8112	5340	4817	3778	2797	1999
TOTAL	33596	30883	28970	28780	39528	49778	52255	49472	46678	42726	39902	36770

Minimum Mean Monthly Flows

Missi Falls	24277	23200	23718	22493	22597	26151	28787	31070	29979	26422	25607	24905
Local Inflow	368	343	307	337	2638	2092	637	1205	454	614	704	569
TOTAL	24645	23543	24025	22830	25235	28243	29424	32275	30433	27036	26311	25474

Maximum Mean Monthly Flows

Missi Falls	51645	44609	38874	33902	44902	73906	83101	72334	66716	64164	59992	56430
Local Inflow	2979	2615	2388	3480	24699	24858	14965	16011	13600	10257	5390	4162
TOTAL	54624	47224	41262	37382	69501	98764	98066	88345	80316	74421	65382	60592

LOWER CHURCHILL RIVER
POST-DIVERSION MONTHLY FLOWS

Average Mean Monthly Flows

	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Missi Falls	2824	1906	1500	2025	10162	25409	18940	15204	8061	8504	6704	5051
Local Inflow	1433	1218	1065	1170	8491	10817	8113	5340	4817	3778	2797	1999
TOTAL	4257	3124	2565	3195	18653	36226	27053	20544	12878	12282	9501	7050

Minimum Mean Monthly Flows

Missi Falls	1500	1500	1500	1500	500	500	500	500	500	500	1500	1500
Local Inflow	368	343	307	337	2638	2092	637	1205	454	614	704	569
TOTAL	1868	1843	1807	1837	3138	2592	1137	1705	954	1114	2204	2069

Maximum Mean Monthly Flows

Missi Falls	14957	6509	1500	13987	52437	73789	49893	40428	32001	34968	29021	21430
Local Inflow	2979	2615	2388	3480	24699	24858	14965	16011	13600	10257	5390	4162
TOTAL	17936	9124	3888	17467	77136	98647	64858	56439	45601	45225	34411	25592

The drastic reduction of the river flow after diversion and especially during the early winter, raised the question of flow reduction to zero for extended periods in midwinter due to complete freeze-up of the river. The present study deals with this aspect of the problem, in particular.

5. AVAILABLE FIELD DATA

Field data supplied by the Study Office and Manitoba Hydro, essentially consisted of the following:

a) Pre- and post-diversion discharges

b) Plan and channel cross-sections

c) Approximate river bed and water surface profiles between Partridge Breast Lake and Red Head Rapids

d) Water surface profiles for various discharges and tide elevations between MH1 and MH30

e) Approximate stage-discharge curves at various lake outlets and river channel sections

f) Some estuary salinity measurements between MH1 and MH30 under high and low tide conditions, with indications on limits of salt water intrusion under present and future flow conditions

g) Some indications on the present winter conditions on the Lower Churchill River and their effect on channel morphology as well as predictions on post-diversion winter conditions and their effect on the river flow.

h) Sets of 1" = 5,000 ft and 1" = 2,640 ft aerial photographs of the Lower Churchill River.

The nature of the field data, the great length of the river covered by the study and the limited time available, imposed certain simplifications of the channel widths and sections between known sections as well as requiring adjustment in their relative elevations.

6. ICE COVER FORMATION AND ACCUMULATION

A. Method of Computation Used

The general procedure and method of computation of the initial ice cover formation and the process of its gradual thickening by jamming or accumulation by transport under the cover used in this study are essentially the same as published in November 1966 by Messers Pariset, Hausser and Gagnon (Ref.: Formation of Ice Covers and Ice Jams in Rivers, Journal of the Hydraulics Division - Proceedings of the American Society of Civil Engineers).

In establishing the ice cover characteristics the following conditions were considered:

a) Discharge

b) Stability of the ice cover

c) River-bed slope and progression of the cover

d) Transport under the ice cover

a) Discharge

To facilitate computation, the discharge was considered to be constant throughout the total length of the Lower Churchill River. Volume of water absorbed by the rising lake and river levels as well as the ice cover itself, would tend to reduce the flow gradually as it moves towards the downstream. The volume absorbed by the rising water level is comparatively small. However, the volume of water absorbed by the ice formation could be significant and for the discharge of 4,000 cfs it could represent a major portion. But, as we move downstream the local inflows add to the river flow. During low flow periods these local inflows could represent 30% to 40% of the flow released at Missi Falls and correspond to the discharge reduced by ice formation (Ref: page 27). So, the use of a constant discharge even for a low flow of 4,000 cfs did not introduce any major error in the ice cover computations.

b) Stability of the Ice Cover

The stability of an ice cover in the process of thickening, either by frazil ice accumulation or by jamming caused by the forces acting on the cover would be governed by the following expression:

$$\frac{BV^2}{C^2 H^2} = \mu \frac{(1-P'/P)\, P'/P\, (t/H)^2 \quad (1-P'/P.\, t/H)^3}{1 + P'/P.\, t/H}$$

where:

B is the width of the channel at the section considered

V is the mean flow velocity considering the complete flow section

C is Chezy's coefficient of roughness

H is the mean depth of flow in the river

μ is a coefficient with an average value of 1.28

P, P' are respectively specific mass of water and ice

t is the ice cover thickness

Using the curve shown on Figure 2, the above expression shows that:

$$\text{I) If } \frac{BV^2}{C^2H^2} = \frac{Q^2}{BC^2H^4} \leq 2.8 \times 10^{-3}$$

The ice cover forms with a thickness corresponding to a point on the curve, say A. After the formation, the cover may thicken due to accumulation of ice and correspond to a point A', or the discharge might decrease and the corresponding point becomes A" without causing destruction of the cover, because, the area enclosed by the curve represents the zone of stable conditions.

However, if the aforementioned changes were more pronounced and corresponded to points B' or B" the cover would be subjected to shoving to attain new equilibrium conditions C' or C".

ii) if $\frac{BV^2}{C^2 H^2} = \frac{Q^2}{BC^2 H^4} > 2.8 \times 10^{-3}$

The cover is unable to form and all the ice moves farther downstream until the water level is high enough to satisfy the following conditions:

$$\frac{BV^2}{C^2 H^2} = \frac{Q^2}{BC^2 H^4} = 2.8 \times 10^{-3} \quad \text{or} \quad H = 4.35 \sqrt{\frac{Q}{C\,(B)^{\frac{1}{2}}}}$$

In other words, the corresponding depth is the smallest at which a cover would form. One might therefore consider this as the critical depth as far as ice cover formation is considered. The relative thickness of the ice cover in this case corresponds to:

$$\frac{t}{H} = 0.4$$

c) River-Bed Slope and Progression of the Ice Cover

In the early stage of winter the Lower Churchill River would be composed of a series of reaches where all possible conditions within the limits of stable and unstable ice cover formation would exist. Thin stable ice covers would form in the lakes and in areas with quiet or slowly flowing water. Ice would be generated in large quantities downstream of the rapids. Heavy accumulation of

ice would take place downstream of each section of the river with rapids or steep initial bed-slope. The process of gradual build up and progression of the ice cover farther upstream may be computed, at a critical section, the depth of flow under the cover, h is approximately equal to 0.6 of the total depth H.

It is therefore possible to compute the flow velocity under the cover as well as the water surface slope, using a standard formula used for backwater calculations, such as the Manning's formula:

$$V = 1.49/n \quad Rh^{2/3} \quad i^{\frac{1}{2}} \quad \text{where: } Rh \simeq 0.3\,H$$

Knowing the water surface slope, it is possible to determine the depth of the water at a section farther upstream. If the depth of flow at this upstream section is greater than the critical depth, the ice cover thickness is directly obtained from the curve in Figure 2. If, however, the depth of flow is less than the critical depth, the ice cover is unable to form until a sufficient quantity of ice has accumulated under the cover already formed. This accumulation depends on the limiting entrainment condition of the ice blocks under the cover.

d) Transport under the Ice Cover

The condition of transport of ice blocks under the cover may be expressed by a type of formula proposed by Meyer-Peter:

$$\frac{U^2}{C^2} = \frac{3.75}{1000} \quad d$$

where: U is the flow velocity under the cover and d the mean dimension of the blocks approaching from the upstream. Using this expression it is possible to determine the thickness and length of accumulation necessary to obtain the required critical depth allowing progression of the cover. However, though the computations of the process of accumulation under the cover is fairly simple; the complete absence of prototype data such as the values of the coefficient of friction, the dimensions of ice blocks, etc., render the computed results rather doubtful when compared in absolute terms. On the other hand, the comparison of computed values of pre- and post-diversion ice cover formation and accumulation remains relatively good and valid.

B. Beginning of Ice Formation

Around the 15th of October the atmospheric temperature starts to fall below the freezing point (Figure 3), and the frazil ice and border ice formation begins in the slowly flowing areas of the river.

Under present conditions the initial ice formation is slightly delayed because of the river water temperature. Water coming out from the depths of the lakes still contains enough sensible heat which must be lost before ice formation can start. After diversion, with the reduction of the flow the total quantity of sensible heat transferred from the lakes would also be reduced. But, as the cooling surface would remain approximately the same, it is expected that the frazil ice formation would most probably begin earlier than that under present conditions. However, the great length of the river downstream of the lake areas would make the over all effect of this early frazil ice formation rather insignificant. For the same atmospheric temperature conditions, though, this would result in an increased quantity of frazil ice formation. The total quantity of ice involved would, however, be very small because the temperatures are still around 32° F, the increase in ice generation would not be very apparent, especially when it is a question of only a day or two more.

C. Process of Initial Cover Formation

Gradually the atmospheric temperature goes down further, the border ice grows and spreads across the channel and the amount of floating ice increases in quantity to such an extent that in areas with relatively low velocities bridging takes place. At this point the floating slush ice or cakes start to accumulate against the fixed cover. The progression pattern of the leading edge depends on the local flow velocity and size of the ice particles or cakes. The slush ice is usually drawn in under the cover and deposited a short distance downstream or accumulates on the surface against the cover.

Under present conditions with the early winter discharge around 35,000 cfs the flow velocity is comparatively high and along the complete length of the river there are only a few areas where bridging could take place. However, after the diversion with reduced flow the possibility of bridging would be greater. Thus the present flow velocities around section MH21 (water intake) prevent the formation of a cover until it has formed farther downstream. All the floating ice moves downstream towards the harbour and is partially evacuated from the harbour during the ebb tide. After the diversion, reduced discharge and the resulting flow velocities around the intake would help the formation of a cover in the early winter and would stop farther downstream movement of floating ice. This beneficial aspect of flow reduction will be treated in more detail later on in this report.

As a general conclusion it may therefore be said that the ice cover would gradually move upstream from a bridged section and that its thickness would increase with discharge.

To investigate in detail this aspect, we have carried out computations of ice cover formation throughout the entire length of the river between Hudson Bay and Partridge Breast Lake for the three following discharges:

- 35,000 cfs, discharge that occurs presently during the early winter as well as that which would represent the spring break-up flow after the diversion

- 4,000 cfs, low early winter discharge after diversion. This is about the minimum discharge below which proper appreciation of the flow section and free surface water profiles become difficult

- 10,000 cfs average early winter discharge after diversion

The results of the computed ice cover are shown on Figures 4, 5 and 6. They give the cover thickness over the complete length of the river studied for the three selected discharges. These profiles show that the thickness increases with discharge and bed slope. Along the long stretches of river with uniform section the cover is practically parallel to the bed slope, however at places, where the bed slope is too steep the cover follows a slope gentler than that of the river-bed. In

areas where the section is wide and deep and the velocities low, an initial cover thickness of 2 ft. has been assumed. But during the course of the winter, this would gradually increase with loss of heat through the ice.

D. Evolution of the Cover After Its Formation

After their formation, as shown on the profiles, the covers would gradually become thicker due to loss of heat through the ice. In areas where the initial cover is very thick there would practically be no further increase. This is generally the case all along the river except in certain areas like lakes or slowly moving flow sections. At the end of the winter the cover thickness in these areas would attain 5 to 6 ft. It is evident that in deep water such increases in thickness would not affect their levels. But in areas with wide and shallow flow sections this would cause a tilting of the cover slope resulting in a corresponding rise of the water level at the upstream end. A reduction in the river discharge might result, if such a rise in water level takes place at the outlet of a lake. But this is rather a hypothetical consideration, because the rate of rise in the water level would be so slow that the storage discharge would be only a small fraction of the total flow.

Complete flow stoppage due to icing of a section of the river, resulting in overtopping of the cover and formation of sheet ice, does not appear to be a probable condition among all the cases studied. In our opinion such a phenomenon can only happen in small shallow streams where the anchored ice cover against the banks is prevented from floating with the water level. In such a case, the increase in loss of heat caused by the thickening of the cover could in effect produce overtopping. But in our case, even for a discharge of 4,000 cfs, the cover would be free to float upward, and the effect of the channel bank or bed unevenness would not be sufficient to cause icing and overtopping.

There is, however, one area where there is some risk of icing. This is situated immediately upstream of the present water intake. Along this part of the river the water level is controlled by the natural bed elevation at Section MH20. After the diversion, these levels would be comparatively lower and the flow not very deep. As the cover would tend to form in the early winter due to the very low flow velocities in this area, it will also be very thin because of the small depth of flow. As the cover thickness increases the water level would remain the same because it is controlled by the Section MH20. This might create a condition for icing. However, the increasing thickness would make the cover unstable and would break it up before it is too thick. The effect of tide fluctuations would also add to the over all instability of the cover in this area. While increasing in thickness, the cover upstream of Section MH21 could only be stable when it is backed up by the cover farther downstream, and the resulting higher water level.

E. Debacle

Unless it is artificially provoked by a premature increase in discharge at Missi Falls, the spring break-up, which depends essentially on atmospheric temperature, would occur around the same time of the year as at present.

The ice thickness would be less than under present conditions since the discharge would be about 35,000 cfs instead of 50,000 cfs. The break-up process would therefore be very similar in nature to that at present. However, local ice jam levels would be comparatively lower. It may be noted here that the ice cover profile shown for 35,000 cfs, calculated for the cover formation under present conditions, could also be used to determine the local ice jam levels during the post-diversion spring break-up, when the same discharge would be running.

7. EFFECTS OF DIVERSION ON THE LOWER REACHES OF THE RIVER

The lower reaches of the river would be subjected to various changes due to the releases at Missi Falls. Brief discussions on some of these aspects are given hereafter. As to the effect of diversion on the water intake and Churchill Harbour, they are treated separately.

A. Water Level

During winter the reduction in river discharge would result in an overall decrease in water levels all along the river and this would be more pronounced as the discharge is reduced.

During spring break-up the levels are expected to be lower than those under present conditions. As a result, it is anticipated that in general the extent of spring flooding in the estuary would be much less than experienced in the past.

In an average year after the diversion, the spring break-up levels would be considerably higher than those caused by the mid-winter cover conditions. A comparison of the cover profiles for 35,000 cfs and 4,000 cfs would give a good indication of the level difference that might be expected. As the average maximum

summer discharge after spring break-up is less than 35,000 cfs, it is certain that some scoured shoreline would be maintained along the major portion of the river. However, their top levels would be lower than those under present conditions, and their widths less. During extreme flood conditions, the greater part of these scoured shorelines would most probably be submerged, but at the same time the preceding spring break-up flood levels would also be higher, and would possibly cause scouring even higher.

A general drop in the lake levels followed by much greater relative rises in spring break-up levels would create conditions undesirable for goose nesting. However, as suggested in the report prepared by the Planning Division of Water Resources Branch in 1971, properly designed rockfill weirs at the control sections of lake outlets would reduce lake level fluctuations to acceptable limits.

B. Ice Cover Thickness

Using the ice cover profiles of Figures 4, 5 and 6, we obtained the following values of ice volumes and mean thicknesses:

Apparent volume of ice accumulation during the process of cover formation:

q = 35,000 cfs	Volume = 23,400 x 10^6 ft^3
q = 10,000 cfs	Volume = 14,400 x 10^6 ft^3
q = 4,000 cfs	Volume = 11,300 x 10^6 ft^3

corresponding mean cover thicknesses:

q = 35,000 cfs	Mean thickness = 18.0 ft
q = 10,000 cfs	Mean thickness = 11.2 ft
q = 4,000 cfs	Mean thickness = 8.7 ft

As the discharge of 35,000 cfs gives an average of present cover conditions, and the other two discharges those for post-diversion, the above figures allow a quantitative evaluation of the effects of diversion on the ice covers.

C. Ice Cover Duration

As we mentioned earlier, the beginning of the ice formation would generally start around the same period of the year. At the downstream, it would appear perhaps a day or two earlier due to the reduction of the flow. The ice cover would also form almost immediately upstream of the pump intake at this time. Though it is difficult to appreciate the precise difference, it may be estimated that this process of ice cover formation would start around October 15, whereas at present it occurs probably around the beginning of November, i.e. about 2 weeks earlier.

Subsequently, due to the loss of heat through the open areas*, the river is completely covered by the end of December or beginning of January under present conditions. After the diversion, similar cover formation would be attained somewhat earlier. Computed probable dates are as follows:

River Discharge	Ice Cover Completion Date
35,000 cfs	January 7
10,000 cfs	December 18
4,000 cfs	December 10

As for the debacle, it is expected to occur around the same period as at present i.e., towards the middle of June.

In brief, it can therefore be said that the total ice cover duration would be slightly longer than it is at present mainly due to its early formation.

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* Daily heat loss was taken at 100 BTU/°F/ft^2. This value was obtained from observation of several similar rivers. The porosity of ice cover was assumed to be 34%.

D. Reduction of Discharge

The following may be the possible sources of temporary flow reduction:

a) Icing

This phenomenon has already been discussed and as concluded earlier we do not anticipate any significant flow reduction from this source.

b) Accumulation of Ice

Ice generated during the formation of the cover is produced at the expense of the river discharge. In lakes, or slowly moving waters, this effect is negligible providing that there is no rapid increase in the lake level due to cover formation. But in rivers, the cover formation is accompanied by an increase in the water level, to compensate for the effects of obstruction to the flow section by the cover, the reduction of hydraulic radius and at times increased roughness. This rise absorbs a fraction of the river discharge; the quantity absorbed may be equal to the volume of the ice cover. Using the ice cover volumes and the corresponding times required for their formation, the reduction in the river discharge may be estimated as follows:

River Discharge	Flow Reduction
35,000 cfs	3,800 cfs
10,000 cfs	2,500 cfs
4,000 cfs	2,200 cfs

However, these figures are based on mean values of monthly temperature and average ice cover progression. In reality, there could be short periods of extreme low temperature when the flow reduction might increase by another 50%. In terms of present discharge, these flow reductions represent only a small percentage of the total flow, but when compared to post-diversion conditions, they are practically equal to the flow remaining in the river. This aspect of flow reduction could have undesirable effects on the aquatic life and the water intake. For this reason we feel that the minimum discharge released at Missi Falls should not be less than 4,000 cfs at least up to the 15th of December. However, by providing adequate storage and regulation at the outlets of one or more lakes downstream of Missi Falls, this minimum discharge of 4,000 cfs may also be assured at the outlet of Billard Lake. This could then reduce the release from Missi Falls to a minimum during early winter months

c) Thickening of Ice Cover

As a result of heat loss through the cover, the thickening cover would absorb a small fraction of the discharge, but this is a very slow process especially when the cover is reasonably thick, as in our case. The flow reduction would be negligible.

d) Storage in Lakes

The rise in the lake levels due to ice cover formation and under present outlet conditions are expected to be as follows:

River Discharge	Rise in Lake Levels	
	BILLARD LAKE	FIDLER LAKE
35,000 cfs	7 ft	6 ft
10,000 cfs	6 ft	4 ft
4,000 cfs	5 ft	1 ft

(No level rise is expected in Northern Indian Lake or Partridge Breast Lake). Assuming that these rises in lake levels would take place over a period of 4 months (Nov-Feb.); i.e., 120 days, the storage discharges then would be as follows:

River Discharge	Storage Discharge	
	BILLARD LAKE	FIDLER LAKE
35,000 cfs	110 cfs	320 cfs
10,000 cfs	75 cfs	120 cfs
4,000 cfs	55 cfs	15 cfs

As mentioned earlier these represent indeed very small percentages of the river discharge, and should not in any way change the river regimes after diversion. It should be mentioned here that in case weirs are constructed at the outlet of these lakes, and depending on the length and height of these weirs, the winter level rises might be practically eliminated.

8. WATER INTAKE FOR THE TOWN OF CHURCHILL

The present water intake for the Town of Churchill is situated about 9 miles from Hudson Bay. A long pipe of about 16" diameter with its centre at approximately EL. 7.0 is used for supplying the intake pumphouse. The intake discharge is about 2 cfs.

A. Present Intake Operating Conditions

Available information does not refer to any major problems regarding the intake operation.

The presence of high winter flows (35,000 cfs) and resulting increased submergence (Figure 7) protects the intake from damage due to impact of ice blocks during spring break-up.

In the early winter, there is some possibility of slush or frazil ice intrusion into the intake without causing serious problems.

No salt water intrusion into the intake has been observed, but maintenance problems due to external corrosion of the watermain between the intake pumphouse and the main pumphouse have been encountered.

B. Effect of Post-Diversion Discharge Reduction on the Intake Operation

The Churchill water intake would probably be subjected to some of the worst effects of the diversion. Provision of a steady flow in the river in winter would not be enough to assure proper functioning of the water supply. Some of the problems we foresee are as follows:

i) During the early winter the intake area would most probably remain free of ice cover because of bridging a little farther upstream. This would facilitate generation of local frazil and anchor ice and their possible intrusion into the intake.

ii) As we have explained earlier the initial "bridge-cover" would tend to become unstable with its increasing thickness or due to the shoving action of the slush and pancake ice accumulating against it. In the event of break-up of this cover the moving ice blocks may either clog or damage the intake pipe because of the latter's proximity to the water surface.

iii) Figure 7 shows the relative open water and ice cover levels with respect to the intake level for various discharges. It is obvious that with a stable ice cover above the intake, for 4,000 cfs the cover would practically touch the intake. Even a discharge of 10,000 cfs may not be adequate to assure proper functioning of the intake in mid-winter.

iv) We have studied the effect of flow reduction on the salt water intrusion in some detail. It was assumed that due to the drastic flow reduction, the salinity in the inner estuary would be considerably increased, and that the stratification of salt and fresh water as well as the fresh water plug would disappear. River flow downstream of Section MH20 would be constantly mixed with the estuary water and the resulting water would have a high salt content. During tides exceeding the steady water level at Section MH20, fresh water would be backed up in the river upstream of Section MH20 only when the critical depth of flow at MH20 is drowned. The volume of river discharge accumulated between the time when the flow at MH20 is submerged, and the time when the tide reaches its maximum, would determine the limit of the salt water intrusion. With increasing tide elevations, the volume of backwater upstream of Section MH20 would increase, and for a given discharge, salt water intrusion would move farther upstream.

Figure 8 shows three typical tides in the Port of Churchill, two of the tides (7.9 ft and 9.6 ft) were computed using the tide at St. John and making necessary corrections (Ref: Tide tables 1972, U.S. Dept. of Commerce). The following table gives the recurrence of various tide heights in the Port of Churchill for the year 1972.

TIDE AT CHURCHILL HARBOUR

MONTHS	TIDE RECURRENCE IN 1972			
	6.5 ft	7.6 ft	7.9 ft	9.25 ft
JANUARY	10	2	1	0
FEBRUARY	12	5	3	0
MARCH	12	8	6	0
APRIL	14	10	7	2
MAY	14	8	5	3
JUNE	13	6	2	0
JULY	10	3	3	0
AUGUST	12	0	0	0
SEPTEMBER	9	3	0	0
OCTOBER	12	5	4	0
NOVEMBER	15	6	6	2
DECEMBER	13	5	5	1

On the basis of these tide elevations and for various river discharges we established the correlation between maximum tide height and the corresponding discharge required to maintain salt water intrusion at Section MH20. Figure 9 shows these correlations. For a river discharge of 4,000 cfs a 7.9 ft tide would cause the salt water intrusion to go beyond the present water intake (Figure 10)

and for 10,000 cfs a tide of 10.5 ft would be required to get salt water to Section MH20 (Figure 11).

v) The increased salinity in the estuary would also increase the external corrosion of the water main between the intake pumphouse and the main pumphouse.

vi) Water quality would change due to the percentage increase represented by the discharges from the tributaries of the Lower Churchill River and also during the snow melting period the water would contain probably more organic debris and tannin.

C. Possible Alternatives to Improve Intake Performance and Safety

The complex nature of the problems involved render a satisfactory solution rather difficult. The following alternatives were briefly examined:

i) The lowering of the intake at its present location would not be a satisfactory solution; this would increase the risks of sediment and salt water intrusion.

ii) Moving the intake farther upstream may not be a desirable solution because of the costs involved. Not only the intake pipe would have to be extended but a new pumphouse might also be required. In addition the intake would have to be lowered to protect it from ice and this, in turn, might recreate the problem of salt water intrusion which might accumulate in low areas upstream of the natural high river bed at Section MH20, during high tides and low river discharges.

iii) Raising the natural control Section MH20 by building rockfill weirs to elevations which would prevent salt water intrusion is an attractive alternative. However, in that case the total rise would have to be obtained in several steps to avoid a steep surface slope hindering navigation. Such a solution would have the following advantages:

- eliminate the risks of salt water intrusion
- would help the formation of a stable cover at the intake area from the beginning of the winter providing satisfactory intake operating conditions
- delay ice formation in the harbour

This arrangement, however, would increase the possibility of silting-up of the intake in the course of time, and also presents the risk of damage to the weirs by ice during break-up.

iv) Creation of a storage reservoir in one of the lakes situated beside the town of Churchill is another interesting alternative. The present intake would be used to supply water to fill the reservoir before freeze-up. In determining the height of the reservoir embankments, a 6 ft ice cover thickness should be taken into account, still leaving the required volume of water beneath to satisfy the winter requirements. We would mention here that a similar solution has been retained for the town of Radisson (LG-2) on the La Grande River, population 6,000.

To conclude, we would recommend that either alternative iii) or iv) be retained. If alternative iii) is retained, a hydraulic model would be very beneficial in determining the optimum size and location of the rockfill weirs, so the following conditions are satisfied:

- stoppage of salt water intrusion
- allow navigation
- formation of stable ice cover
- reduction of risks of silting-up of the intake

If alternative iv) is retained, special measures would be required to protect the intake from ice impact, and pumping should be avoided during the period of frazil ice formation and during high tides and low flow periods.

9. EFFECT OF DIVERSION ON THE PORT OF CHURCHILL

A. Present Flow Conditions

The harbour is situated just upstream of the mouth of the Churchill River, on the south bank of the estuary (Figure 12). The configuration of the estuary is rather unusual because of a very narrow section at the river mouth. The combined effect of the river topography and the harbour location subject the dock face to strong currents, especially during the ebb tide. Information supplied by Manitoba Hydro on velocity measurements carried out on October 11, 1968, at a point situated on the north end of the dock (Figure 13), indicates the following:

- maximum velocity during flood tide:- 1.3 ft/s
- maximum mean velocity during ebb tide: 4.5 ft/s over the total depth
- maximum surface velocity during ebb tide: 6 ft/s

Knowing that the corresponding tide amplitude was about 11 ft and the Churchill River discharge 42,000 cfs, we have attempted to calculate the above mentioned velocities. But, though the computed velocity for the flood tide agrees well with the measured one; the mean computed ebb velocity is only 3 ft/s instead of 4.5 ft/s measured (Figure 13). This difference is explained by the strong flow concentration along the berthing area and the location of the prototype velocity measurements. (Figure 12). In his report on Churchill Harbour (December 1966) Mr. T.M. Dick describes this aspect of the flow pattern in some detail.

As for the surface velocity of 6 ft/s, it is probably the result of a vertical flow concentration at the surface, caused on the one hand by the estuary bed configuration (flow moving over high shoal approaching deep channel along the dock), and low density river water flowing along the surface on the other hand. It is difficult to separate the individual effects of each of the above mentioned factors on the actual velocities; only a hydraulic model could give precise answers to these questions. However, with a view to assessing the overall effect of diversion, we have tried to analyse the above aspects in the following manner.

B. Flow Condition after Diversion

i) It is almost certain that a flow reduction in the river would result in an increase in the flood velocities and a reduction in the ebb velocities.

ii) The horizontal and vertical flow concentrations due to the effect of estuary bed configuration would remain unchanged, but the surface flow concentrations due to the salinity differences would probably be considerably modified.

After diversion, and as a direct result of the drastic flow reduction, it is anticipated that the estuary salinity would be radically changed. A mixed flow with high salinity would replace the present stratified flow with a thick interface of brackish water with low salt-content.

Taking into account the factors mentioned above, and assuming an 11 ft tide at the north end of the dock, we obtained the following surface velocities for two given river discharges, (42,000 cfs pre-diversion and 12,000 cfs post-diversion):

FLOOD TIDE		EBB TIDE	
Pre-Diversion	Post-Diversion	Pre-Diversion	Post-Diversion
1.3 ft/s	1.7 ft/s	6 ft/s	4.5 ft/s

A river flow of 4,000 cfs would further improve the velocity patterns.

C. Present Ice Regime in the Port

i) Under present conditions, in the absence of local bridging effects, large quantities of ice flow down the river in the early winter. Arriving at the estuary this ice floats on a layer of cold fresh water at 32°F, which prevents its being melted by the warmer sea-water below. A large amount of ice is also formed by the cold fresh water flowing over the shallow mud flats in the estuary.

ii) Evacuation of the estuary ice depends largely on the strong current during the ebb tide. However, this does not take place until the density of the surface covered by the ice is very high; hence the crowding of the port by early ice. As the winter progresses, under the effect of shoving due to high local ebb velocities, a very thick ice plug forms around the north end of the present dock.

iii) Even when the volume of ice is not excessively large, the surface flow pattern in this area creates a concentration of ice along the dock face. This hampers berthing, and the moving ice flowing along the dock jams between the dock face and the ships' bows, ultimately exerting heavy loads on the mooring lines.

iv) Dredging is required to maintain the deep channel along the dock.

D. Post-Diversion Ice Regime in the Port

i) As has been discussed earlier, the flow reduction in the river would facilitate early winter local bridging just upstream of the Churchill water intake. This would also stop practically all floating ice from reaching the estuary. As the most effective bridging is likely to occur with smaller discharges, it would be desirable from this point of view to have a river discharge of about 5,000 cfs around the 15th of October.

To assist in the formation of an early and reliable ice bridge the use of a floating boom just upstream of the water intake could be very effective. In that case, a stable bridge would be assured even for river discharges of 10,000 cfs or 12,000 cfs. However, the boom would have to be fairly long and, consequently, it would be expensive. It seems, therefore, that the idea of reducing the discharge to an optimum value, and construction of small rockfill weirs (as mentioned earlier in relation to the water intake) would increase the probability of formation of an early, stable ice bridge.

ii) The ice bridge having stopped all the floating ice, none would therefore reach the estuary. In fact, even if a few blocks of ice do escape, or some ice is formed locally inside the estuary during the low tide or in areas of fairly quiet water, these would melt readily in the relatively warm sea water during the high tide. Because of complete mixing at the upstream end of the estuary, the layer of cold fresh water now present in the estuary would disappear.

iii) The mixing of fresh and salt water at the upstream end of the estuary would also cause the disappearance of ice formation along the nearby coasts, which are saturated with stratified fresh water. At times this fresh surface water and the resulting early ice formation extends several miles outside the port.

iv) And last of all, we would briefly describe a phenomenon which under certain conditions could contribute to the formation of ice-crystals throughout the winter even where the water is covered with a thick ice cover. This particular process of ice formation would occur in the upper end of the estuary where a well-defined statification of salt and fresh water exist. Fresh water at 32° F coming in contact with sea water at 30° F loses heat and ice crystals are generated. It is possible that under present conditions this process takes place at the upper end of the estuary as well as along the sides providing added thickness.

After diversion, the flow reduction and resulting disappearance of stratification would practically eliminate ice formation by this process.

E. The Effect of the Proposed 1,200 ft Breakwater (Deflector Dyke)

Figure 12 shows the approximate location and size of the deflector dyke proposed by the Churchill Development Board.

It is assumed by the Board that this construction would increase the capacity of the Harbour both in docking facilities and storage area as well as improve the present problems related to ice and silt movement.

In our opinion, the precise overall effect of such a construction may only be determined on a properly designed hydraulic model. However, it is possible to foresee some of the consequences of the proposed construction. Briefly, they are as follows:

1) Ships at the dock would be sheltered from the strong frontal velocities during the ebb-tide.

ii) Concentration of floating ice against the dock during the ebb-tide would be reduced, but the formation of an ice plug at the north end of the dock is still possible.

iii) Sweeping longitudinal flows along the dock would be replaced by eddies of major proportion which might add to the docking difficulties at certain times of the tide.

iv) Formation of eddies would encourage deposition of sediment in the dredged channel along the present dock.

v) A triangular area between the proposed dyke and the existing dock may be prone to formation of early winter sheet-ice under present river discharge conditions.

vi) Encourage formation of fast border-ice on the southern side of the dyke.

vii) With reduced river discharge and resulting decrease in the early winter ice inflow, the need for protection against ice just before the closure of the navigation season would be less acute.

In our opinion it would be preferable to carry out adequate model studies before undertaking such a construction and if possible, wait until the Churchill Diversion becomes effective, so the new flow and ice condition are better known. Under post-diversion conditions it might be that a southward extension of the existing dock facilities would be a better choice.

10. CONCLUSIONS

Comparative studies of the present and post-diversion ice regimes of the Lower Churchill River and their relative consequences presented in this report allow us to draw the following conclusions:

i) Under average post-diversion discharge conditions the river flow would be maintained throughout the winter.

ii) Under extreme minimum discharge and low-temperature conditions the volume of discharge required by the ice formation may be very close to the river flow.

iii) Post-diversion stable ice cover levels would in general be much lower than those at present. However, average-year spring break-up ice level and movements should maintain some scoured shoreline in the lower reaches.

iv) After diversion, level fluctuations in the lakes would be considerably increased. However, properly designed rockfill weirs at the lake outlets would reduce these fluctuations and re-establish conditions required by the existing wildlife.

v) Reduction of the river discharge would adversely affect the operation of the present water intake for the Town of Churchill. Alleviation of the problems would require major scale projects.

vi) Reduction of the river discharge would have several beneficial effects on the Port of Churchill. Ice inflow into the estuary would be considerably reduced and the final freeze-up date would be delayed by at least 15 days.

vii) The proposed 1200' long dyke at the southern end of the harbour would have very limited usefulness and might even create some new sources of problems.

11. RECOMMENDATIONS

Based on the foregoing studies and conclusions the following recommendations may be made.

i) To assure formation of a stable ice cover and required downstream river flow in winter, a minimum discharge of 4,000 cfs should be maintained at Missi Falls or at the outlet of Billard Lake up to at least the 15th of December.

ii) To assure proper functioning of the Churchill water intake two alternative solutions may be envisaged:

a) Construction of rockfill weirs at river Section MH20.
The optimum locations and heights of the weirs to be determined by a scale model study.

b) Development of a storage lake beside the town of Churchill and provision for adequate protection of the present intake.

iii) Before taking the final decision to construct the 1,200 ft dyke, proper hydraulic model studies should be undertaken to ascertain and optimise the usefulness of such a structure.

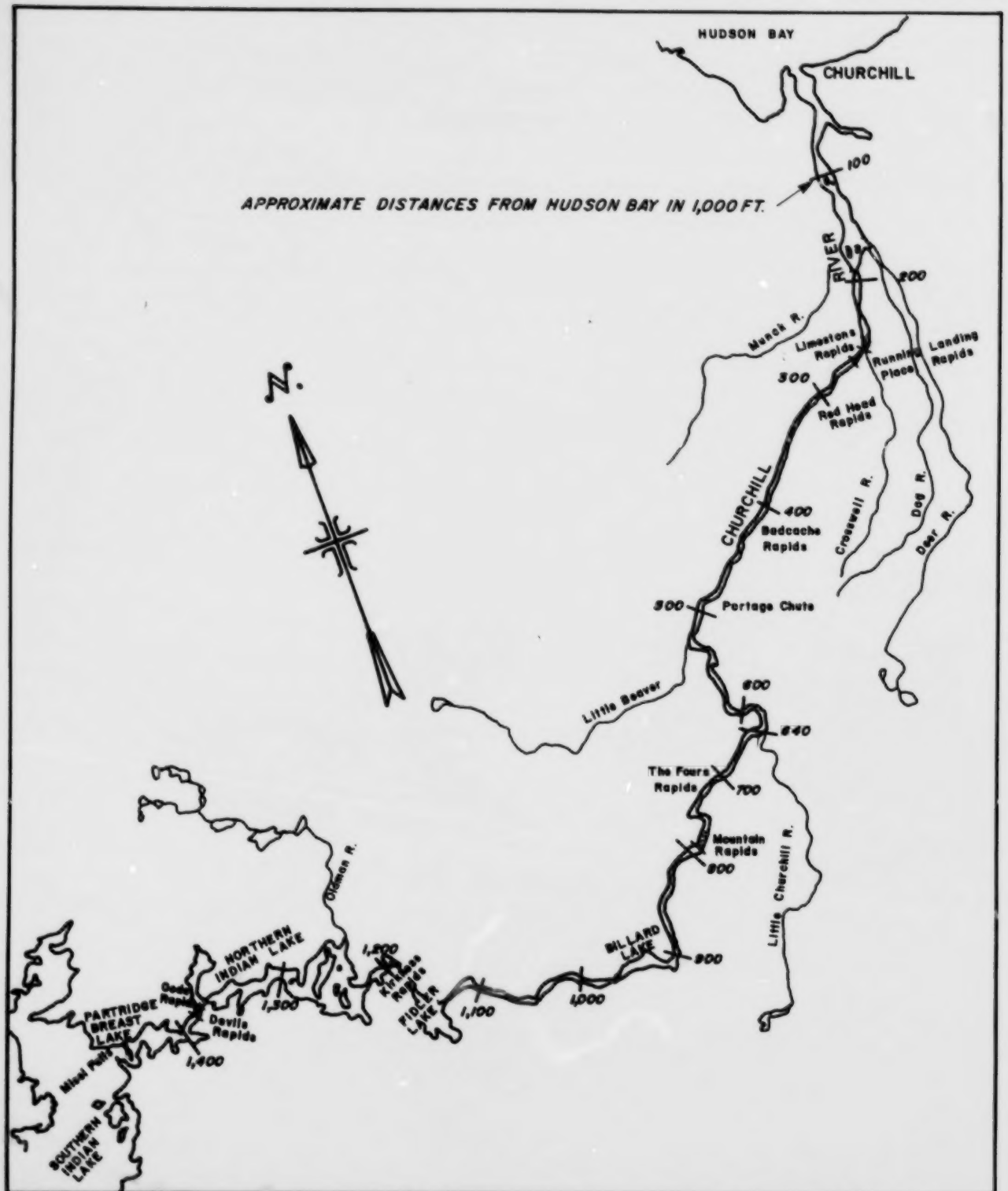

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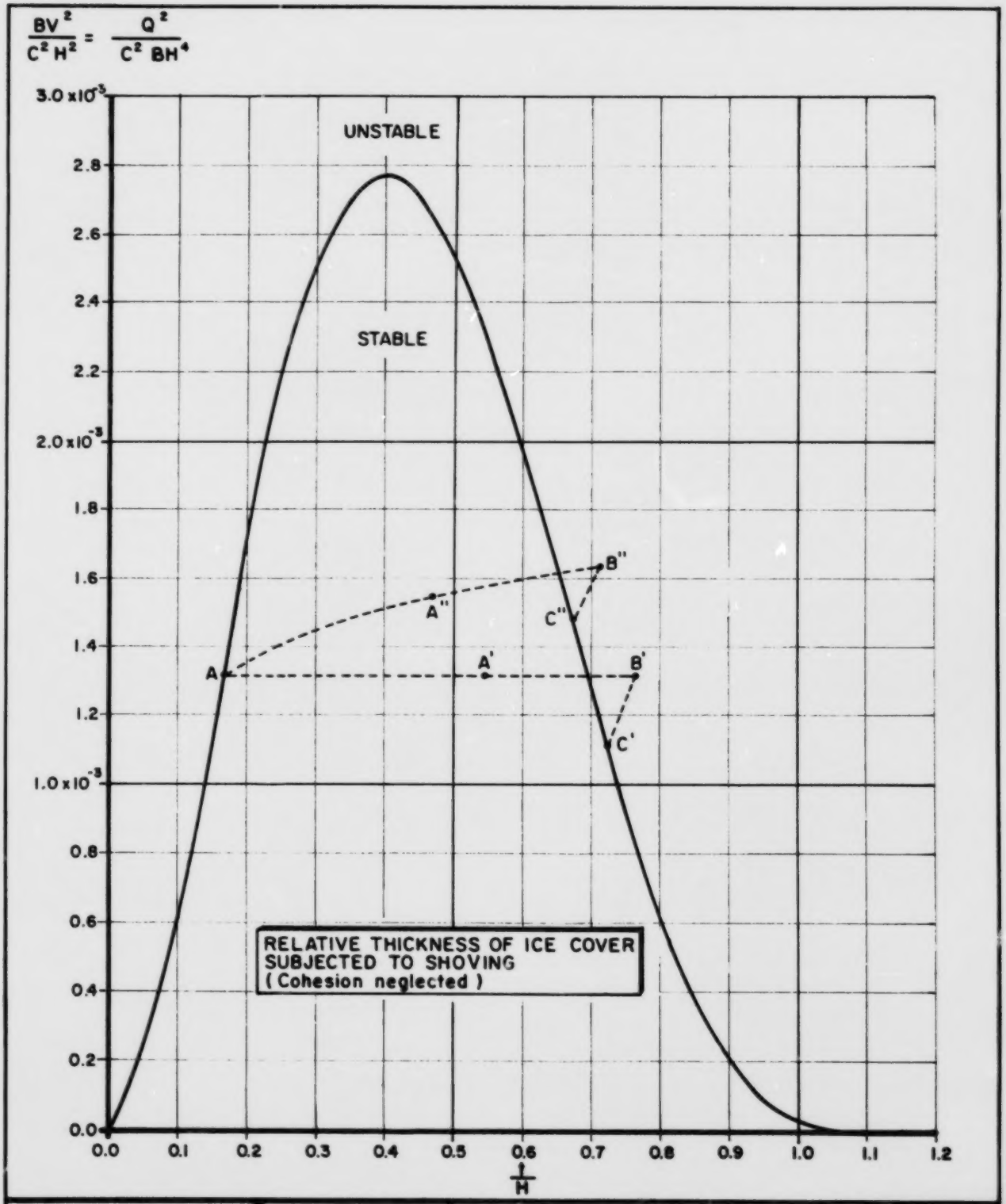
FIG. 1

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

CHURCHILL RIVER
MISSI FALLS TO HUDSON BAY
LOCATION PLAN



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DATE: APRIL, 1974

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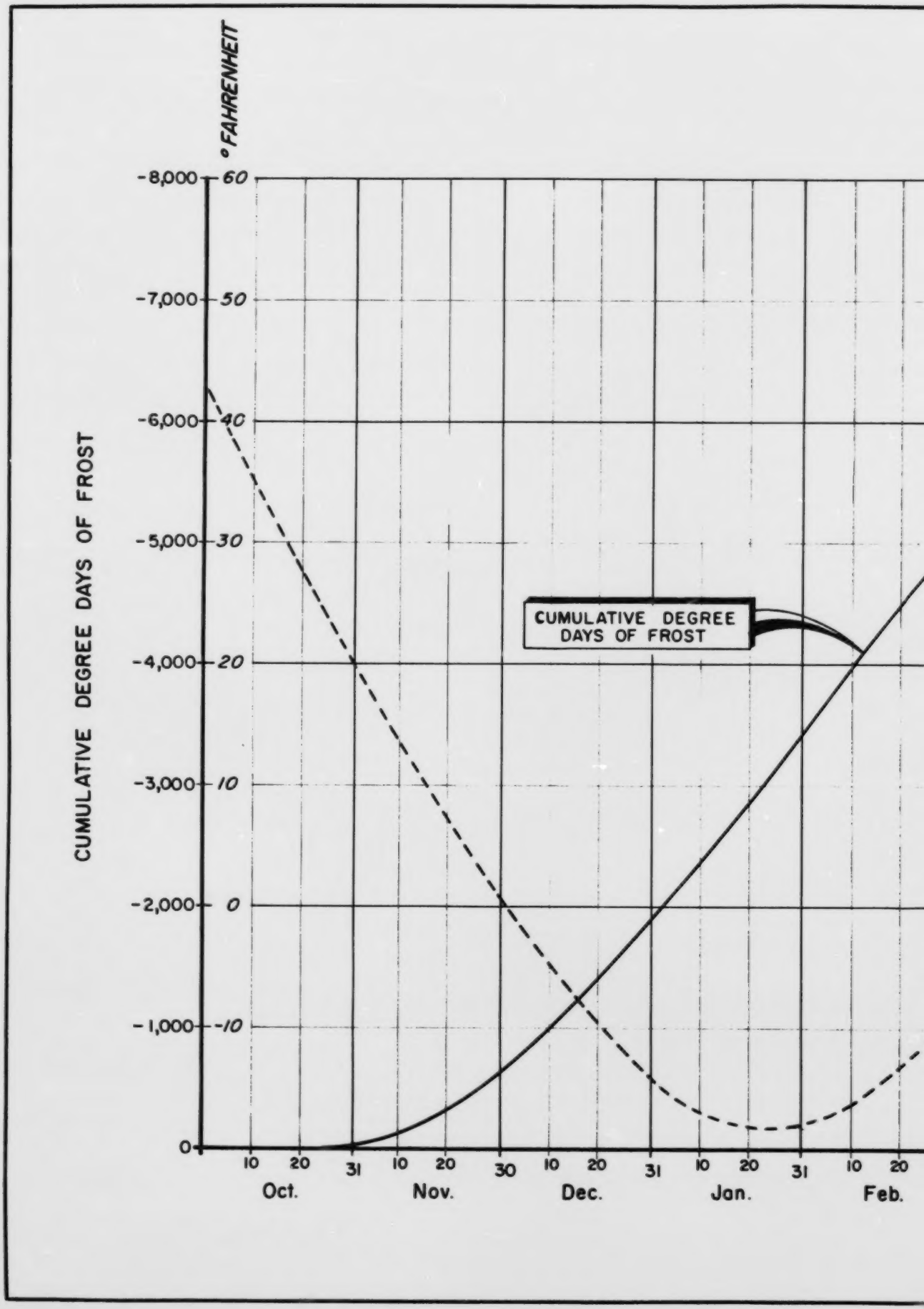
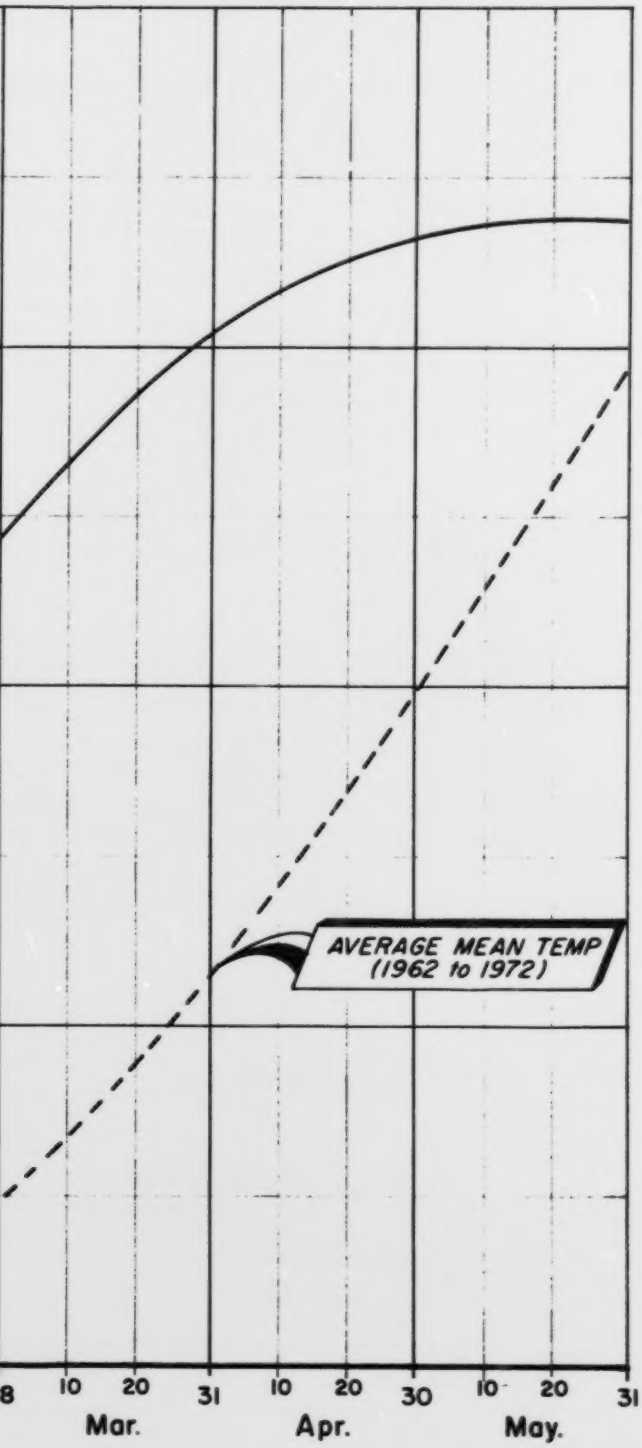
FIG. 2

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

ICE COVER STABILITY DIAGRAM


°FAHRENHEIT
CUMULATIVE DEGREE DAYS OF FROST
-8,000
-7,000
-6,000
-5,000
-4,000
-3,000
-2,000
-1,000
0
60
50
40
30
20
10
0
-10
CUMULATIVE DEGREE DAYS OF FROST
10
20
31
10
20
30
10
20
31
10
20
31
10
20
Oct.
Nov.
Dec.
Jan.
Feb.



LABORATOIRE
D'HYDRAULIQU
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LOWER
POST-DIVERSI

AVERAGE MEAN
AT THE TOWN OF
AND THE CORRES
DAYS OF FROST

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LAKE WINNIPEG, CHURCHILL and NELSON RIVER STUDY BOARD

SCALE ÉCHELLE:

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

DATE: APRIL, 74

DRAWN BY DESSINÉ PAR: S G

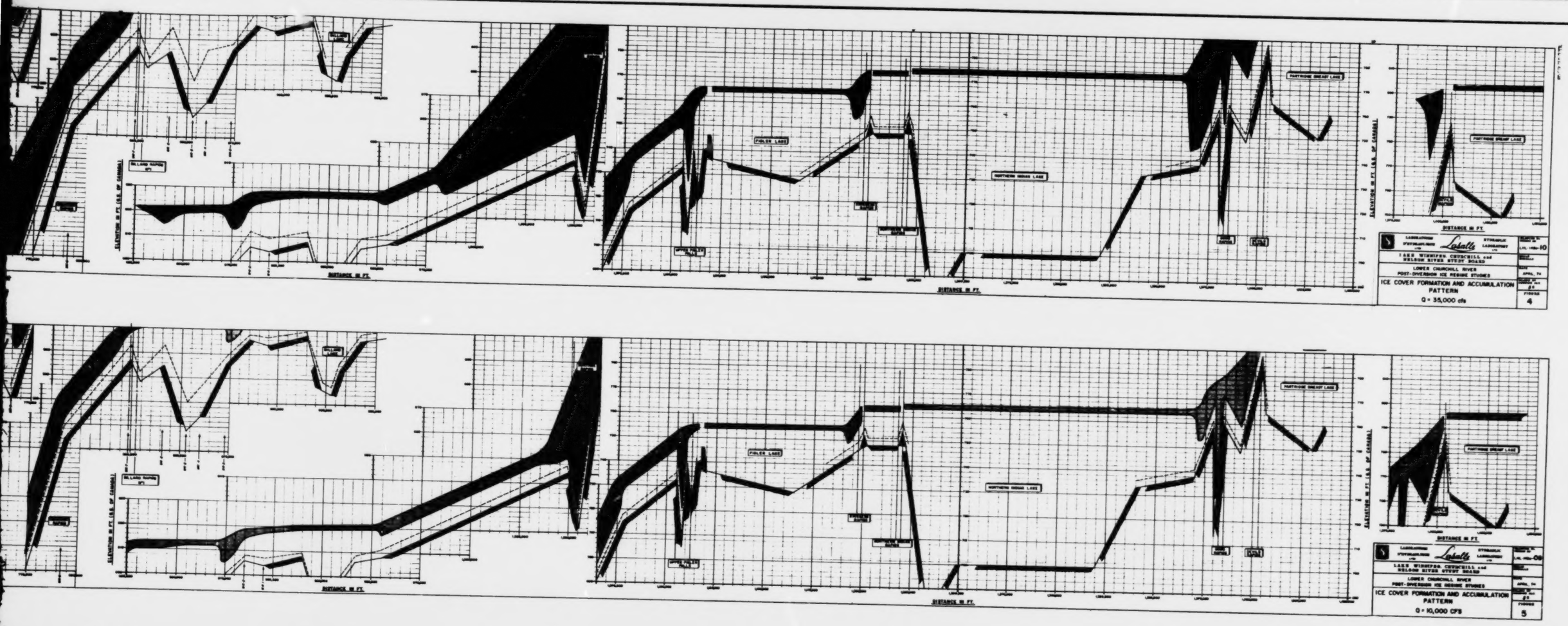
AVERAGE MEAN MONTHLY TEMPERATURE IN °F AT THE TOWN OF CHURCHILL (1962 to 1972) AND THE CORRESPONDING CUMULATIVE DEGREE DAYS OF FROST

FIGURE 3

BEGINNING OF WINTER
DISTANCE IN FT.

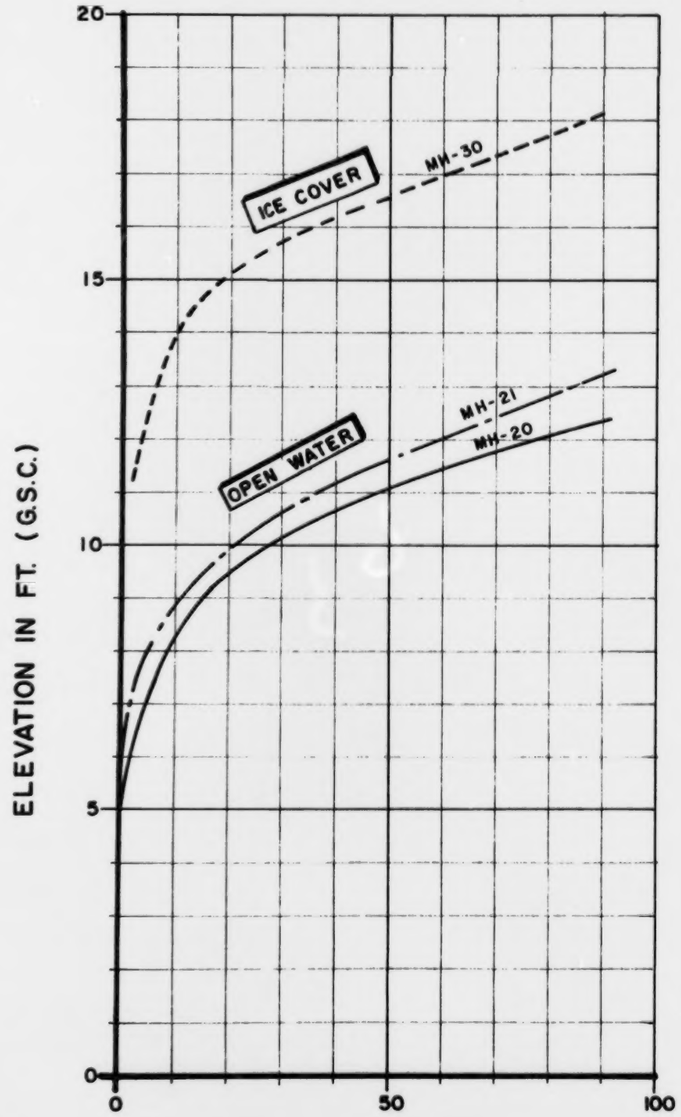
END OF WINTER
BEGINNING OF WINTER
DISTANCE IN FT.

END OF WINTER
BEGINNING OF WINTER
DISTANCE IN FT.

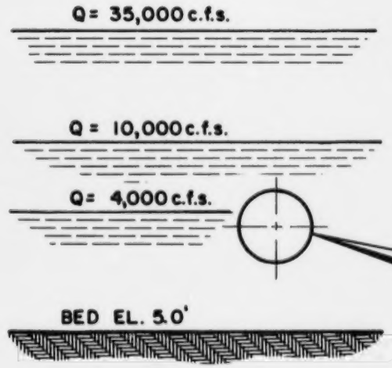

WILLIAM RAPIDS
FIDLER LAKE
NORTHERN INDIAN LAKE
PARTRIDGE BREAST LAKE
DISTANCE IN FT.
ELEVATION IN FT. (B.S. OF DATUM)
LABRADOR HYDRAULIC LABORATORY
LAKES WINNIPEG, CHURCHILL and NELSON RIVERS STUDY BOARD
LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES
ICE COVER FORMATION AND ACCUMULATION PATTERN
Q = 35,000 cfs
APRIL 74
4

WILLIAM RAPIDS
FIDLER LAKE
NORTHERN INDIAN LAKE
PARTRIDGE BREAST LAKE
DISTANCE IN FT.
ELEVATION IN FT. (B.S. OF DATUM)
LABRADOR HYDRAULIC LABORATORY
LAKES WINNIPEG, CHURCHILL and NELSON RIVERS STUDY BOARD
LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES
ICE COVER FORMATION AND ACCUMULATION PATTERN
Q = 10,000 CFS
5

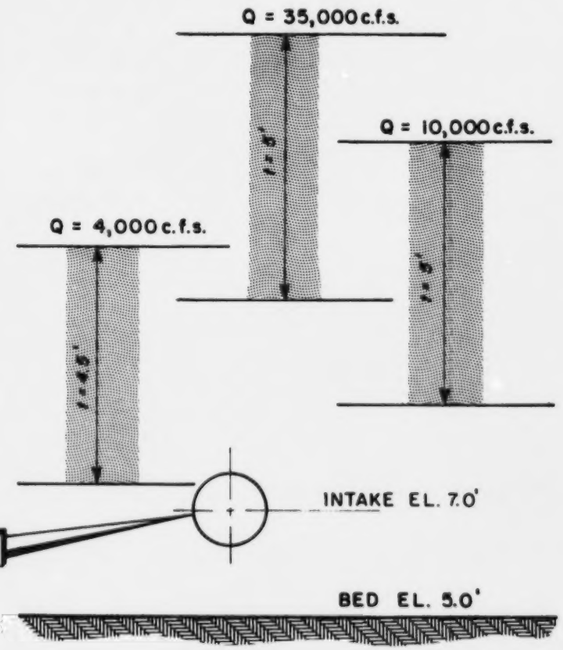
WILLIAM RAPIDS
FIDLER LAKE
NORTHERN INDIAN LAKE
PARTRIDGE BREAST LAKE
DISTANCE IN FT.
ELEVATION IN FT. (B.S. OF DATUM)
LABRADOR HYDRAULIC LABORATORY
LAKES WINNIPEG, CHURCHILL and NELSON RIVERS STUDY BOARD
LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES
ICE COVER FORMATION AND ACCUMULATION PATTERN
Q = 4,000 CFS
6



OPEN WATER CONDITION



ICE COVER CONDITION



LABORATOIRE D'HYDRAULIQUE LTÉE

LAKE WINNIP
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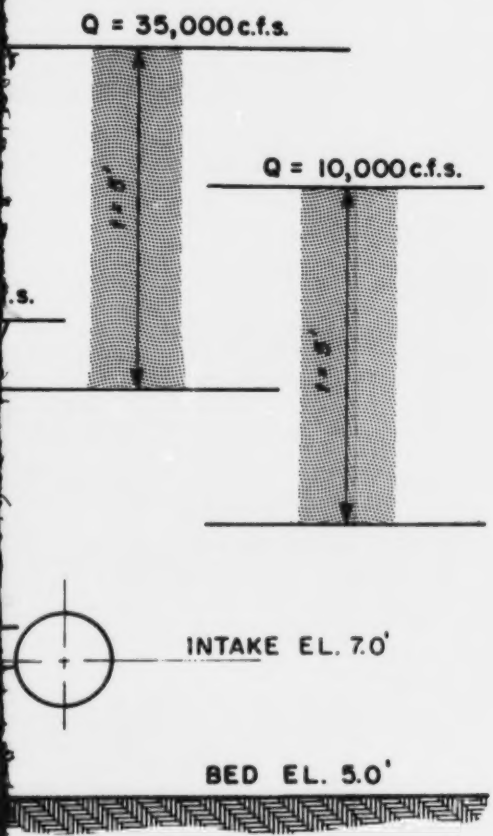
LOWER C
POST-DIVERSION

STAGE-DISCHARGE & THICKNESS WIT WATER INTAKE LO

COVER CONDITION



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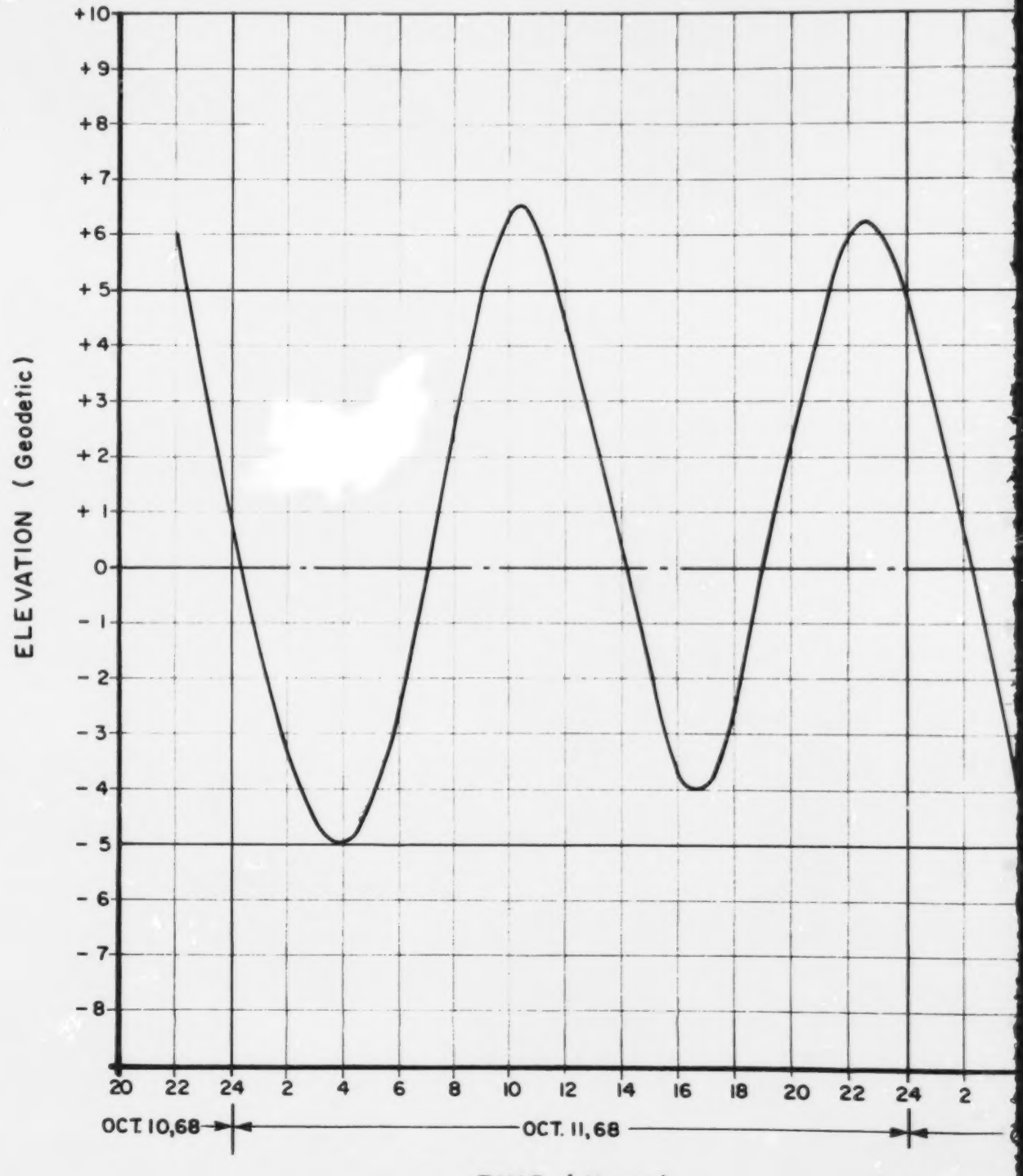
LAKE WINNIPEG, CHURCHILL and NELSON RIVER STUDY BOARD		SCALE ÉCHELLE
LOWER CHURCHILL RIVER POST-DIVERSION ICE REGIME STUDIES		DATE APRIL, 74
STAGE-DISCHARGE, ICE COVER ELEVATION & THICKNESS WITH RESPECT TO PRESENT WATER INTAKE LOCATION		DRAWN BY DESSINÉ PAR JG
		FIGURE 7

6.5 ft. TIDE



(Ref.: Manitoba Hydro Dwg : 0520-C-0311 0)

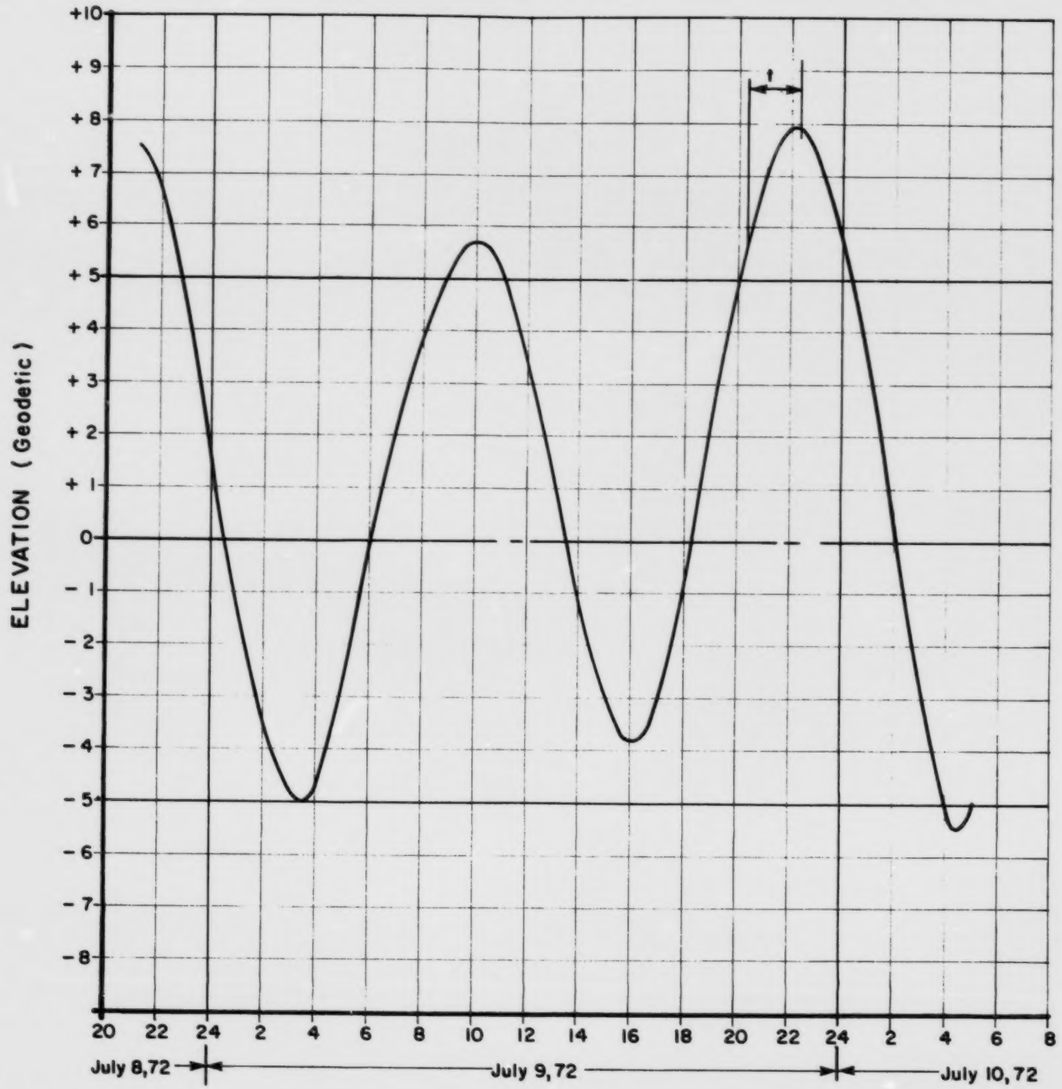
TIDE

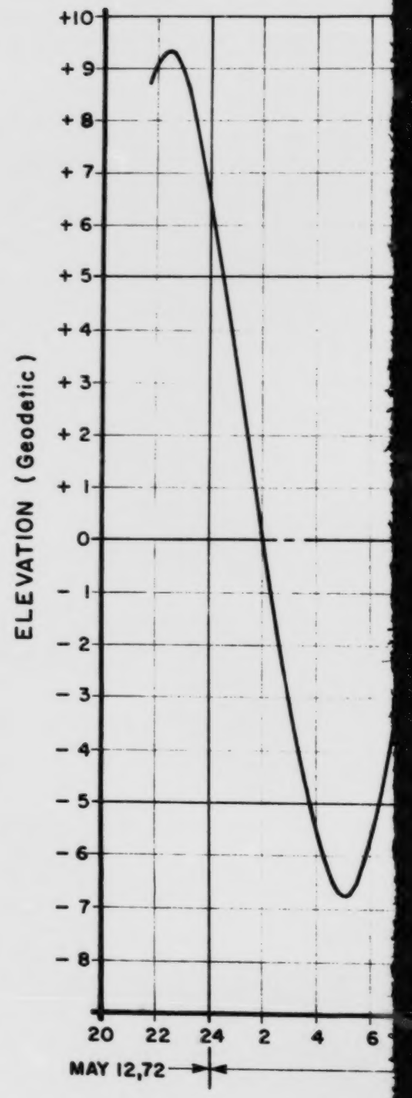
s)

: 0520-C-0311 0)

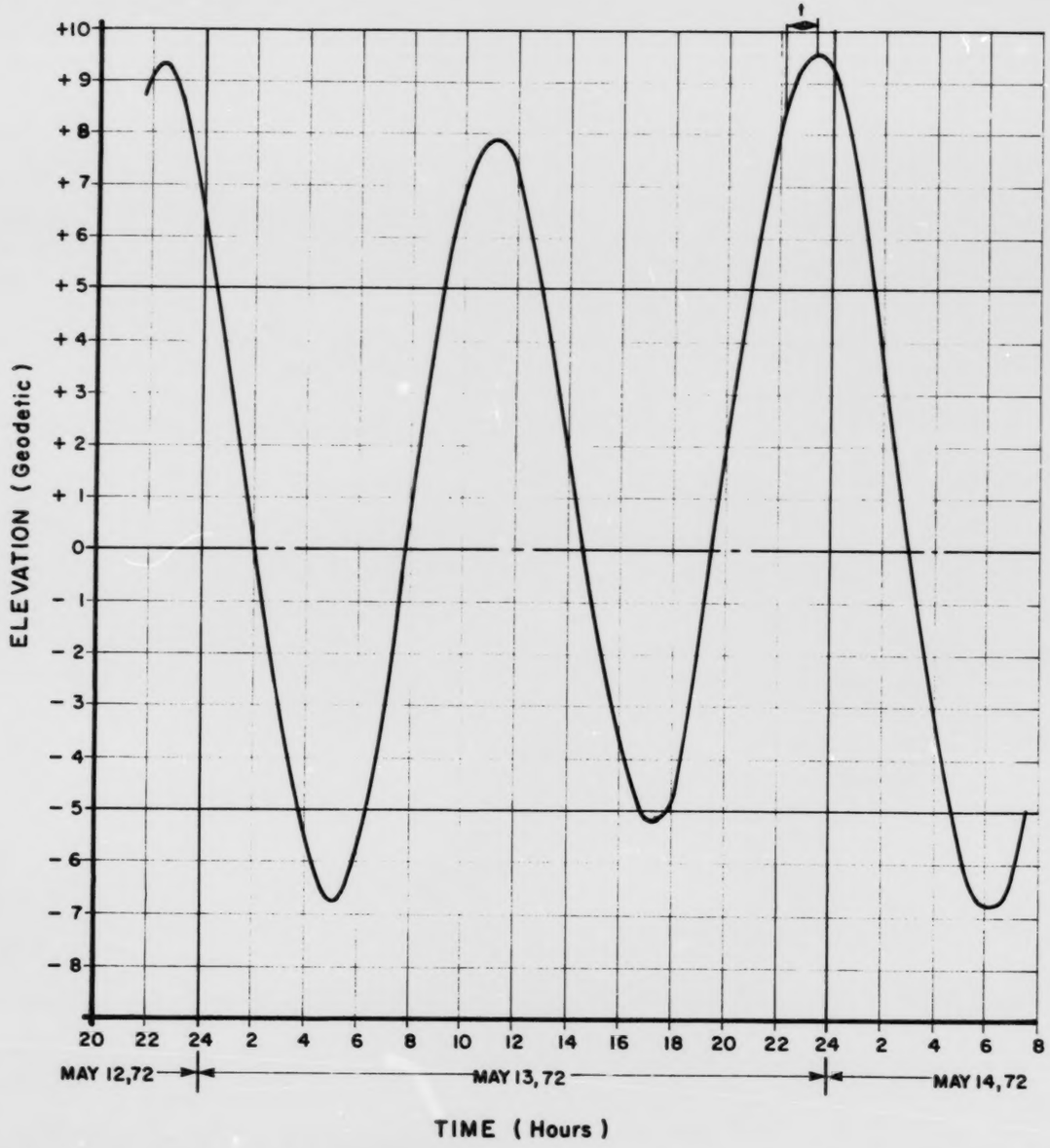
7.9 ft. TIDE

t from 6.8' to 7.9' = 1.25 hrs = 4,500 sec.





9.6 ft. TIDE



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LAKE WINNIPEG, CHURCHILL and NELSON RIVER STUDY BOARD

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

TYPICAL TIDES AT CHURCHILL

(Converted from tides at St. John, N.B.)

(Ref.: Tide Table 1972 U.S. Dept. of Commerce)

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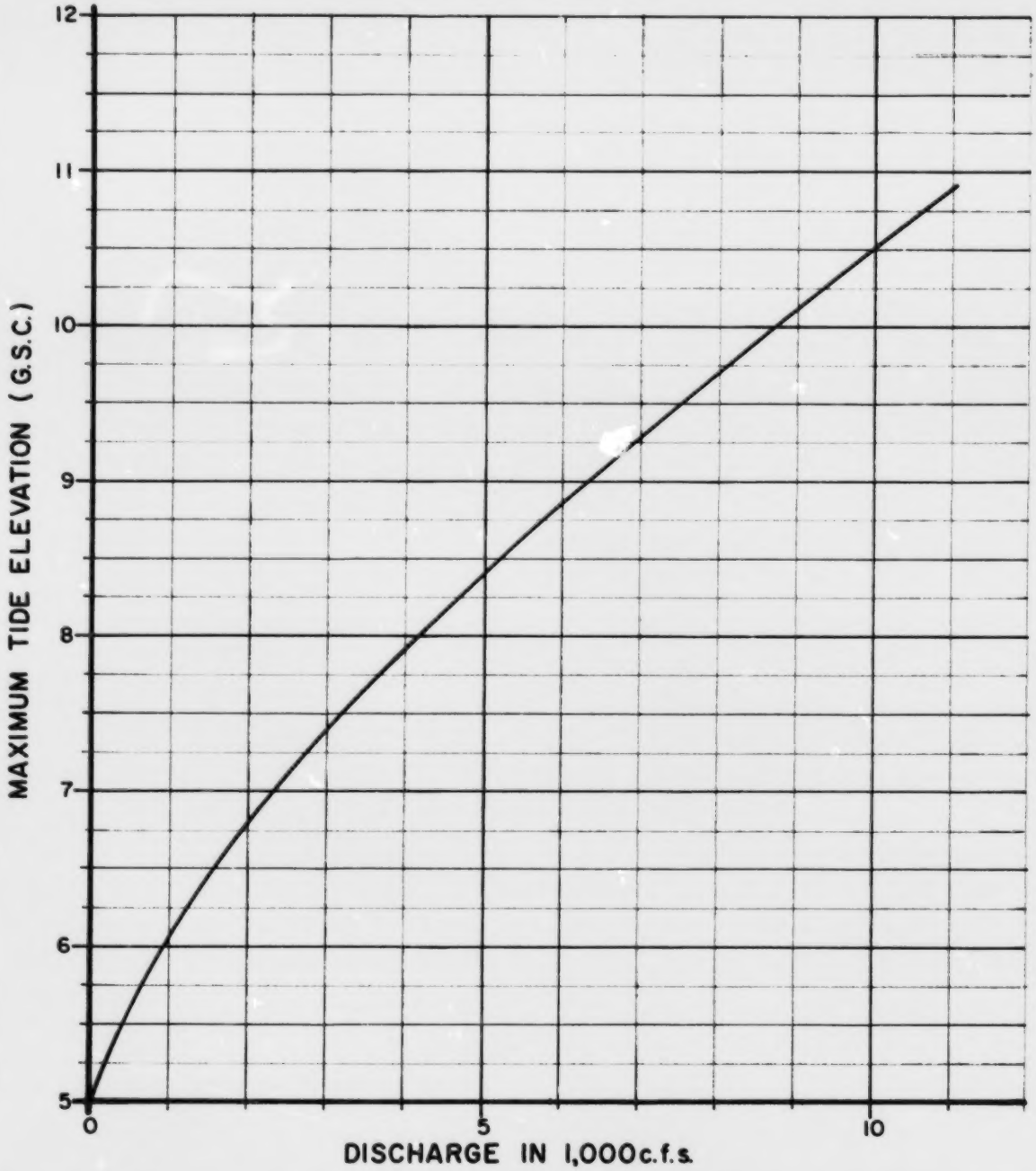
SCALE ÉCHELLE:

DATE: APRIL, 74

DRAWN BY DESSINÉ PAR: EG

FIGURE: 8



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LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

DISCHARGE REQUIRED TO PREVENT SALT WATER INTRUSION BEYOND CROSS SECTION MH-20 AS A FUNCTION OF MAXIMUM TIDE ELEVATION

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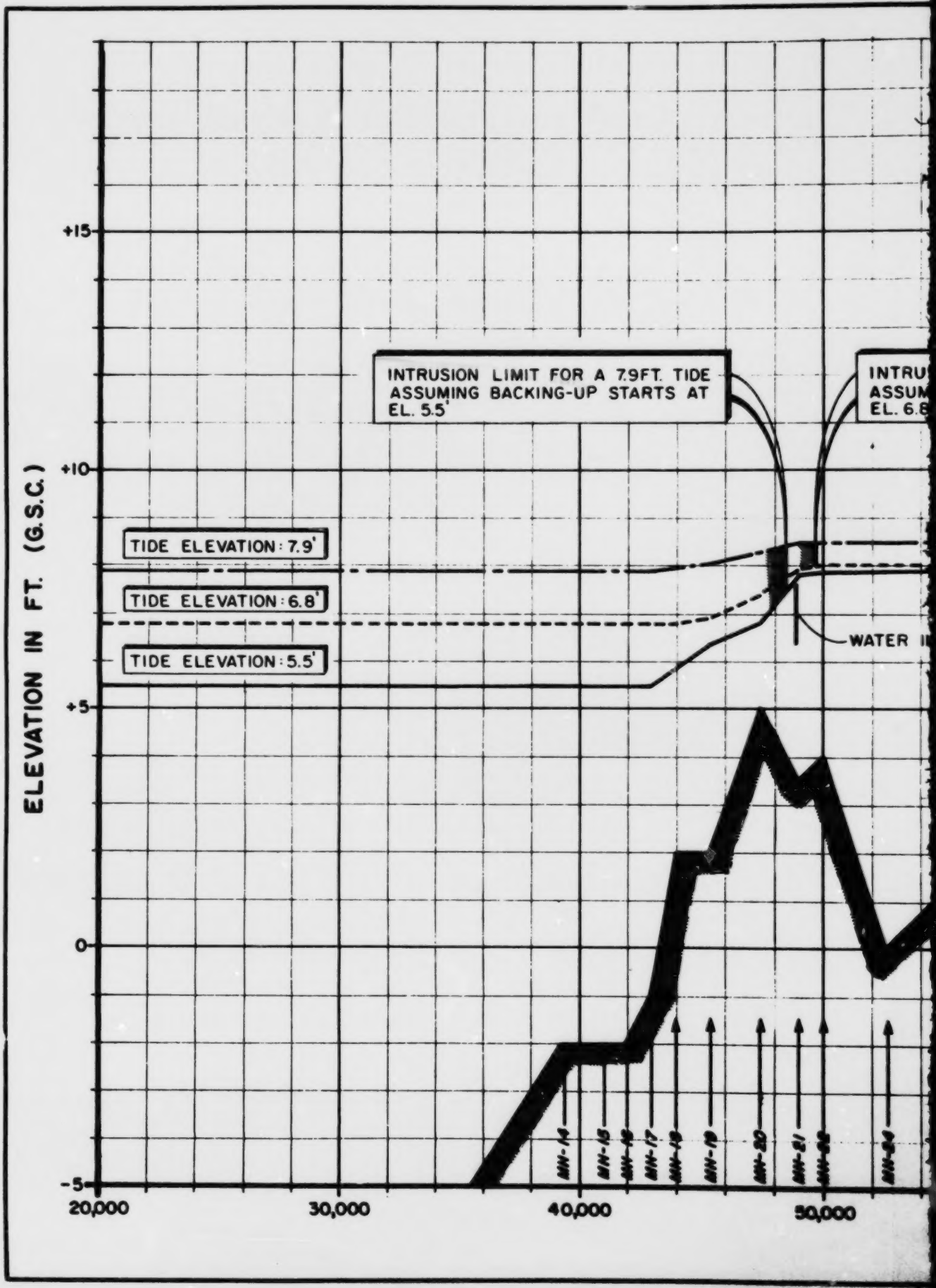
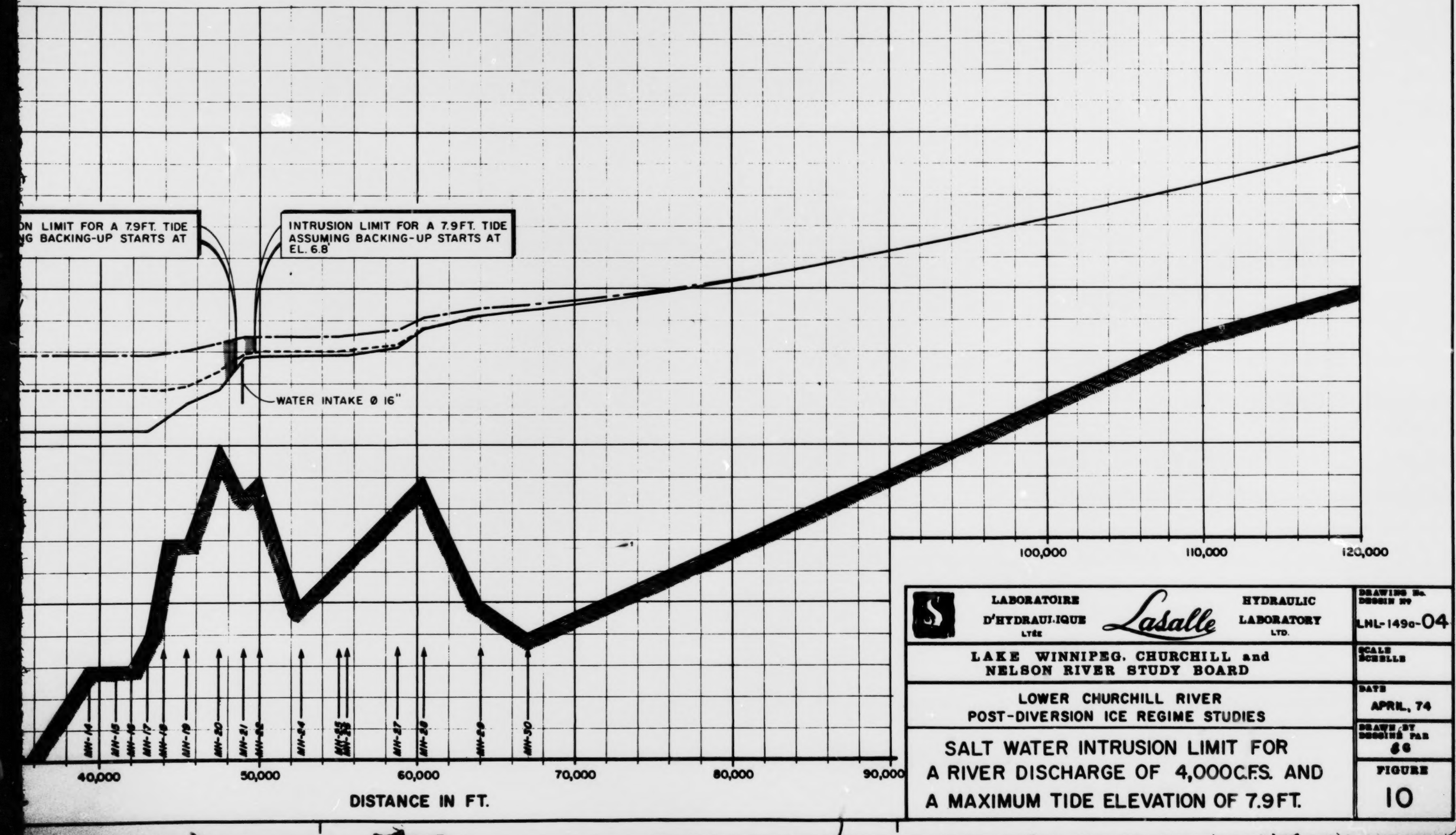
SCALE - ÉCHELLE:
DATE: APRIL, 74
DRAWN BY - DESSINÉ PAR: JG
FIG. 9


ELEVATION IN FT. (G.S.C.)
+15
+10
+5
0
-5
20,000
30,000
40,000
50,000
INTRUSION LIMIT FOR A 7.9FT. TIDE ASSUMING BACKING-UP STARTS AT EL. 5.5'
TIDE ELEVATION: 7.9'
TIDE ELEVATION: 6.8'
TIDE ELEVATION: 5.5'
WATER
MW-14
MW-15
MW-16
MW-17
MW-18
MW-19
MW-20
MW-21
MW-22
MW-24



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LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

SALT WATER INTRUSION LIMIT FOR A RIVER DISCHARGE OF 4,000C.F.S. AND A MAXIMUM TIDE ELEVATION OF 7.9FT.

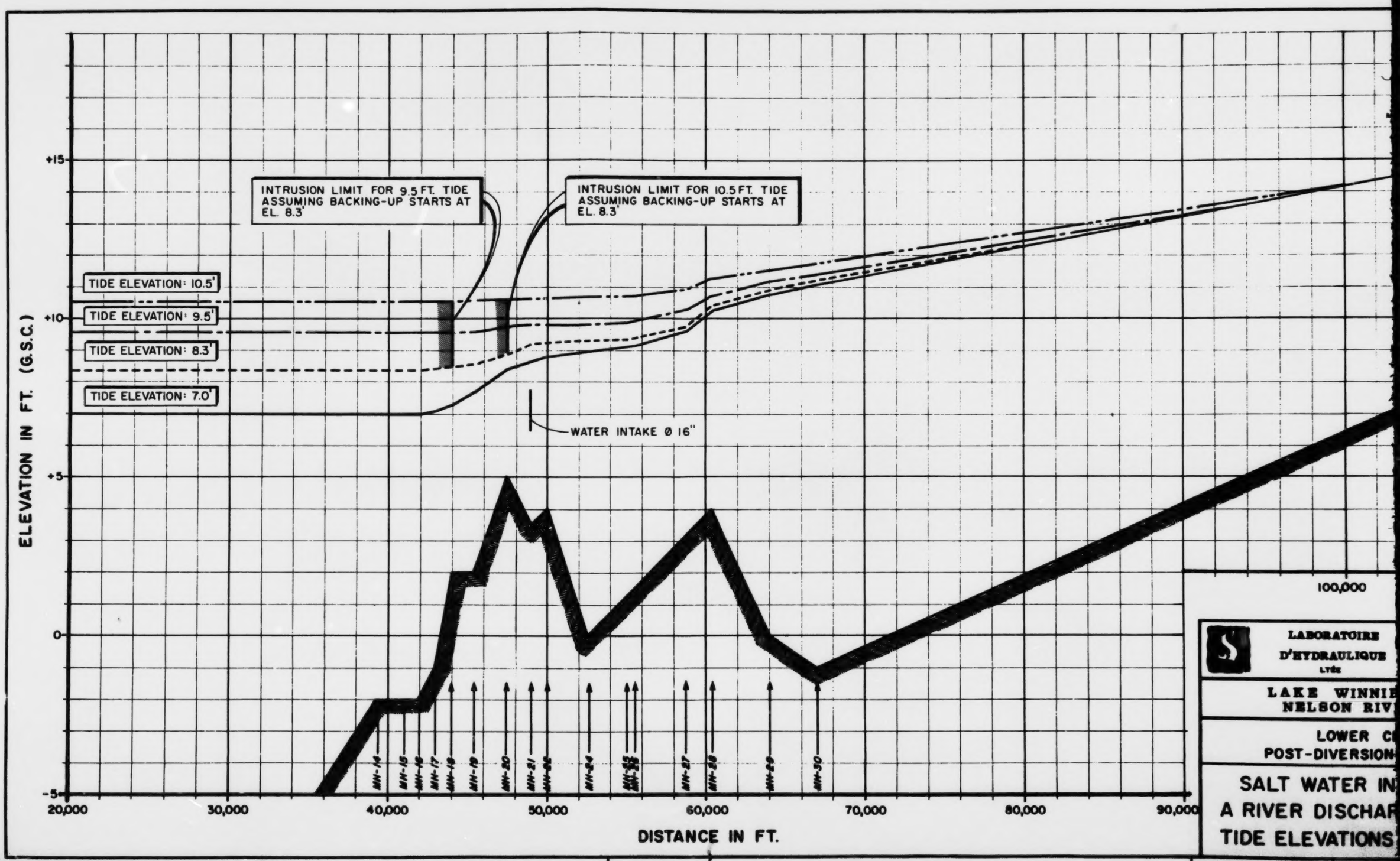
DRAWING No. DESSIN Nº: LNL-1490-04

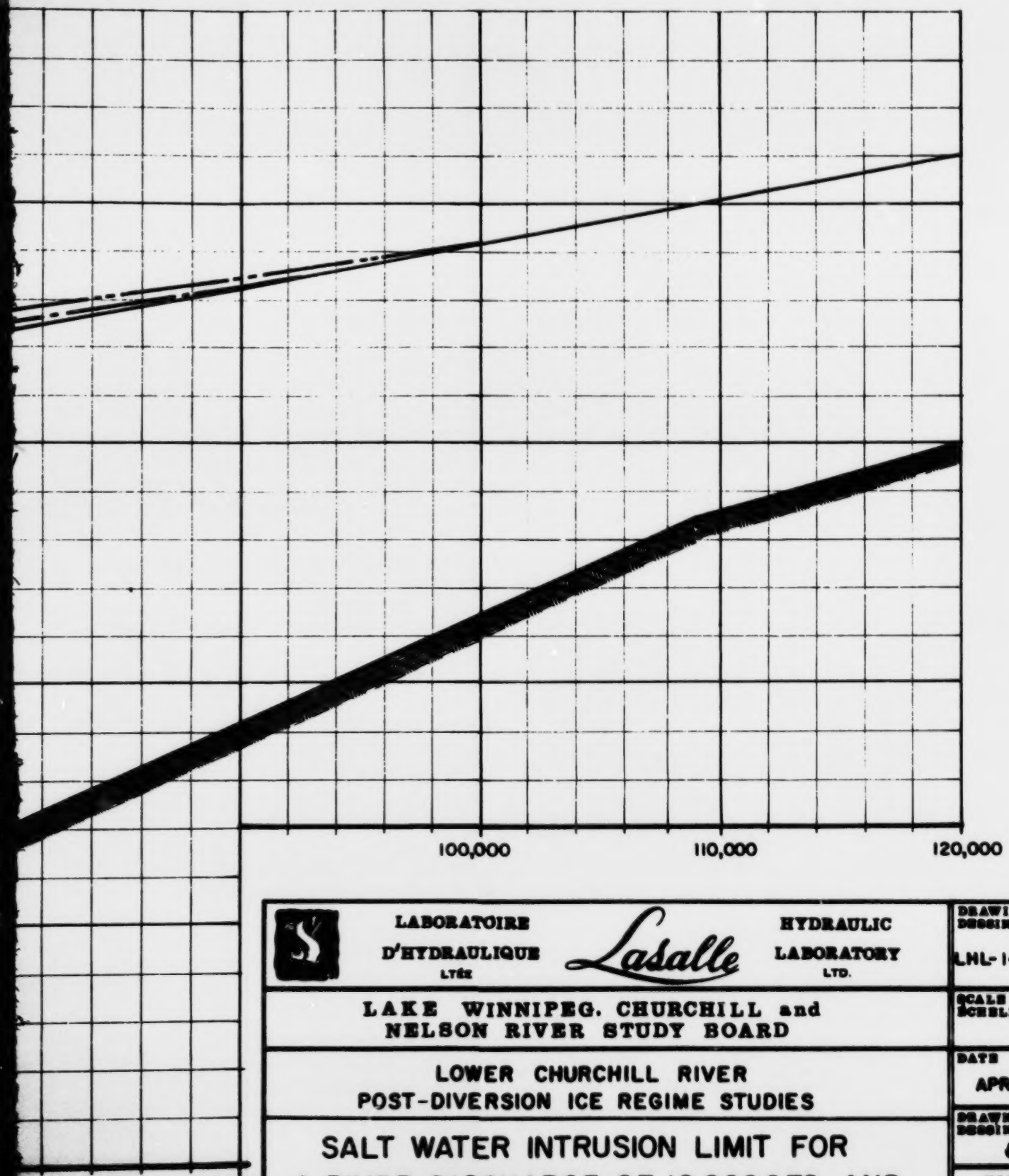
SCALE ÉCHELLE:

DATE: APRIL, 74

DRAWN BY DESSINÉ PAR: GG

FIGURE: 10


INTRUSION LIMIT FOR 9.5 FT. TIDE ASSUMING BACKING-UP STARTS AT EL. 8.3'
INTRUSION LIMIT FOR 10.5 FT. TIDE ASSUMING BACKING-UP STARTS AT EL. 8.3'
TIDE ELEVATION: 10.5'
TIDE ELEVATION: 9.5'
TIDE ELEVATION: 8.3'
TIDE ELEVATION: 7.0'
WATER INTAKE Ø 16"
ELEVATION IN FT. (G.S.C.)
+15
+10
+5
0
-5
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
DISTANCE IN FT.
LABORATOIRE D'HYDRAULIQUE LTÉE
LAKE WINNIP
NELSON RIV
LOWER C
POST-DIVERSION
SALT WATER IN
A RIVER DISCHAR
TIDE ELEVATIONS



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SCALE ÉCHELLE:

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

DATE: APRIL, 74

DRAWN BY DESSINÉ PAR: GC

SALT WATER INTRUSION LIMIT FOR A RIVER DISCHARGE OF 10,000C.F.S. AND TIDE ELEVATIONS OF 9.5FT. AND 10.5FT.

FIGURE: 11

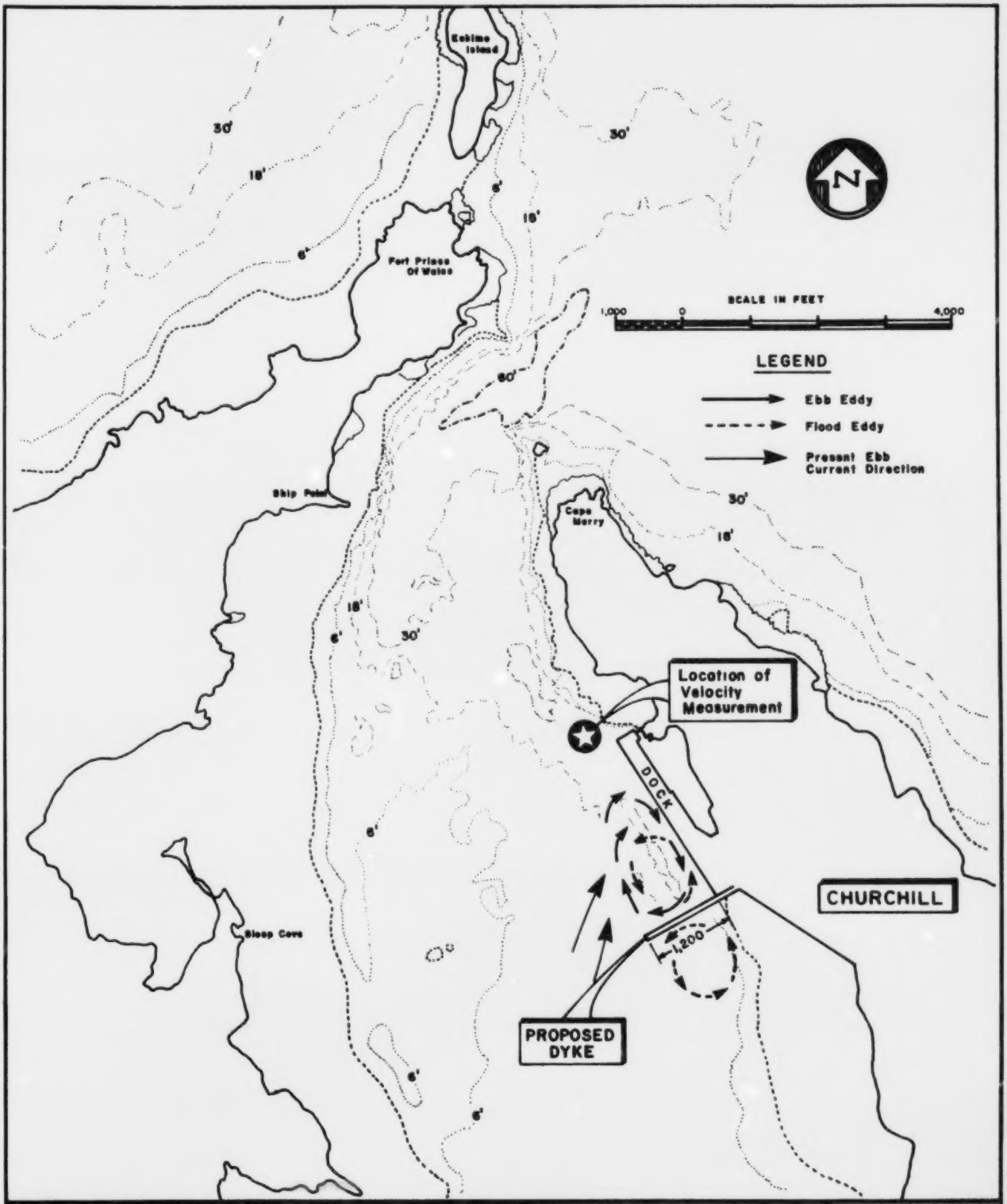

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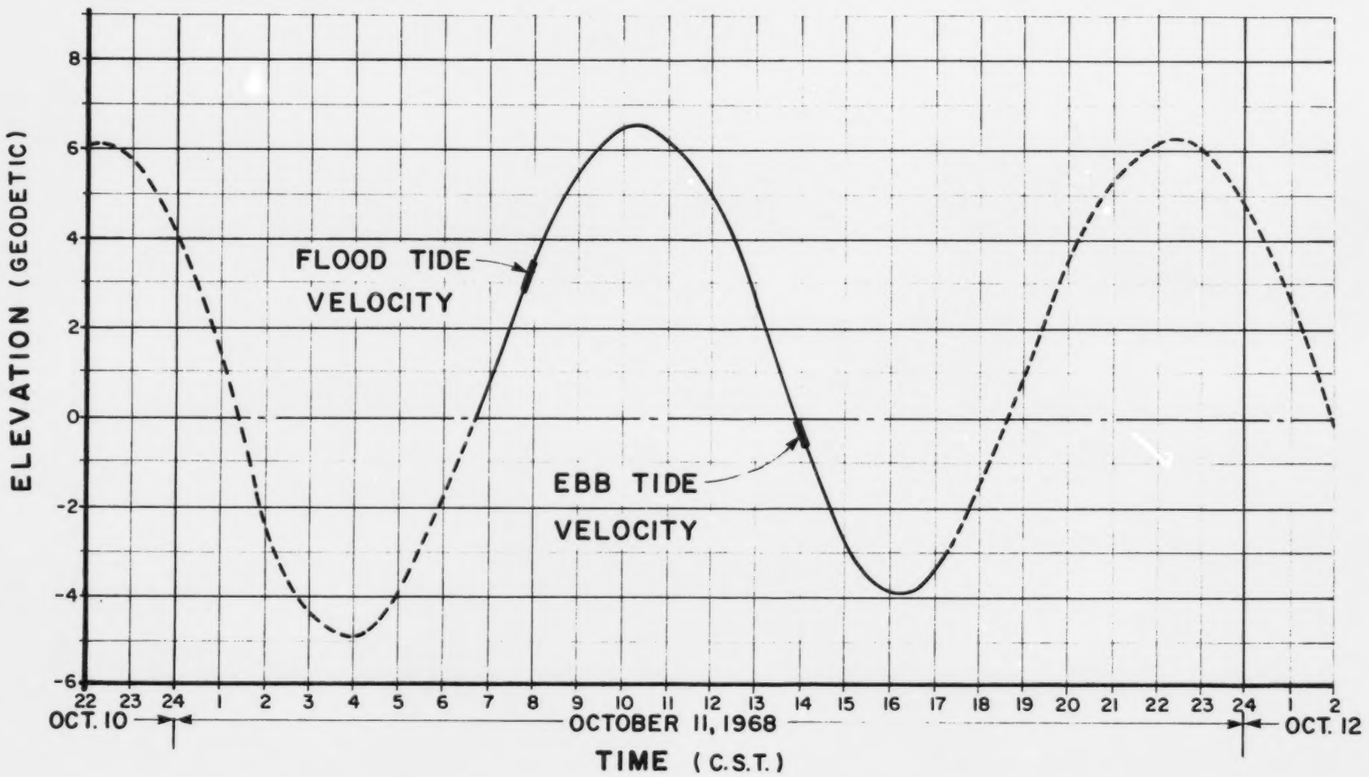
FIG. 12

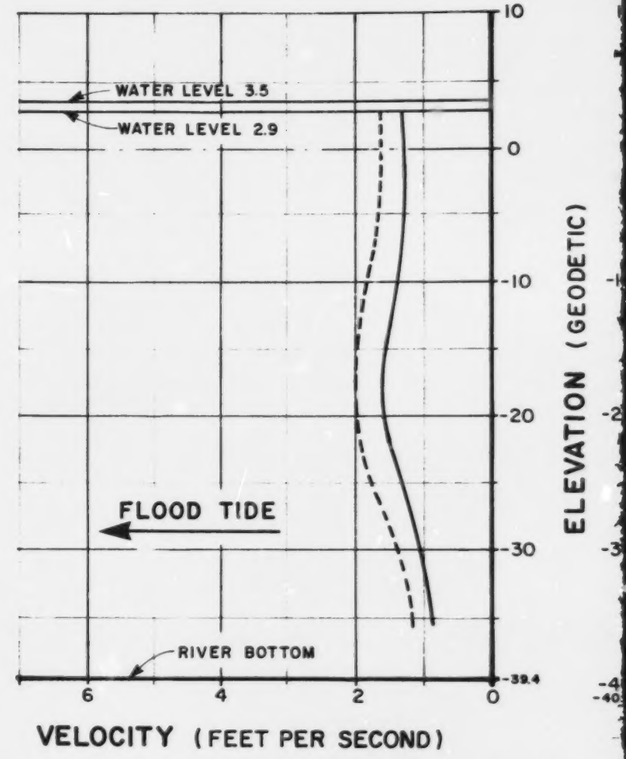
LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES

CHURCHILL HARBOUR

LOCATION OF VELOCITY MEASUREMENT AND FLOW PATTERN DUE TO TIDES

TIDAL CYCLE





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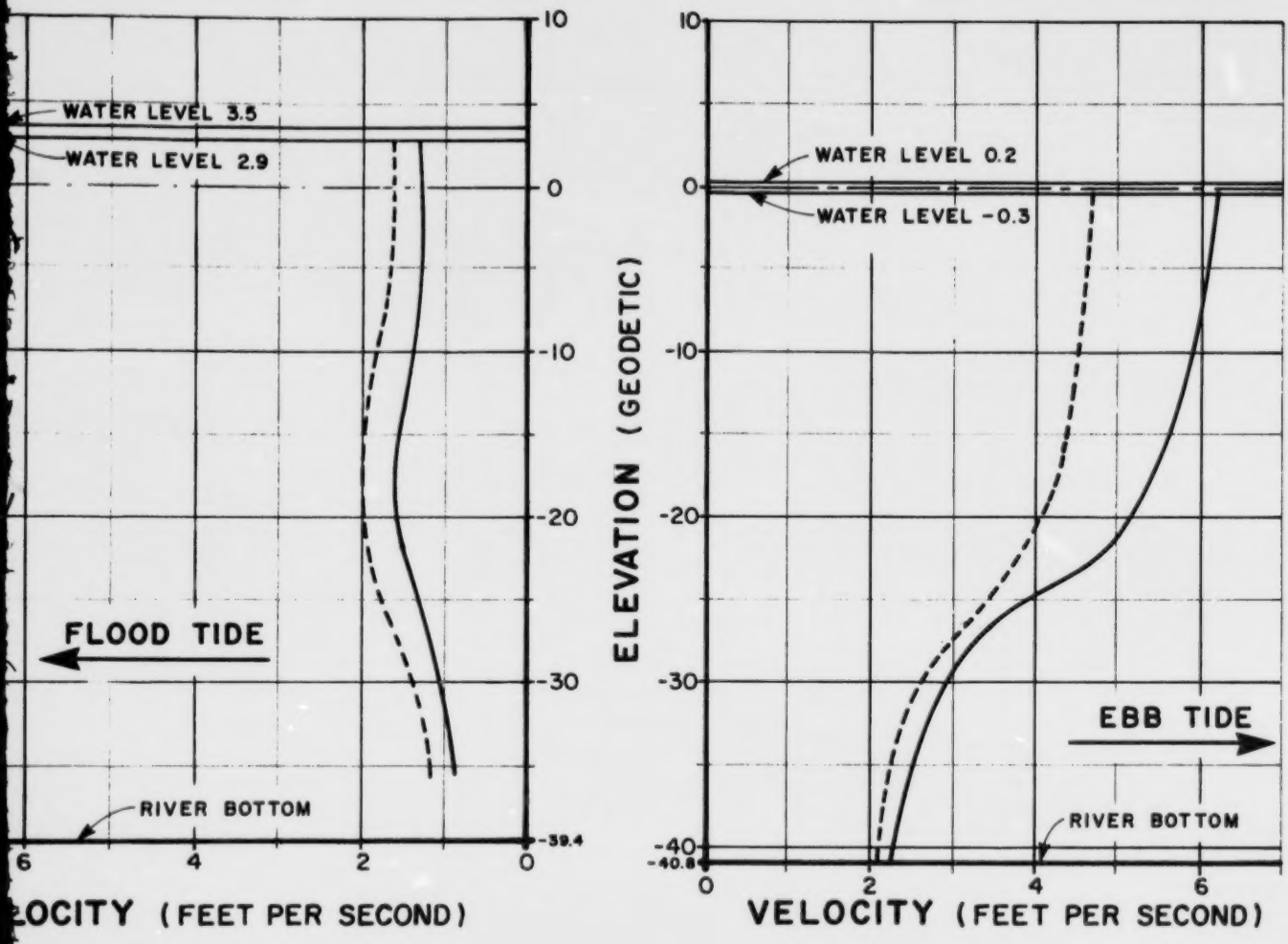

——— MEASURED Q_{RIVER} = 42,000c.f.s.

---------- COMPUTED Q_{RIVER} = 12,000c.f.s

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EAST CHANNEL HYDRAULIC STUDY

EAST CHANNEL HYDRAULIC STUDY

by

D. G. RAMSEY
Planning Division, Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba
November, 1973

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

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I - INTRODUCTION

Manitoba Hydro is constructing works in the West Channel of the Nelson River which will permit Lake Winnipeg to be regulated. The works comprise excavated channels which increase the outlet capacity of Lake Winnipeg, and a hydroelectric generating station near the mouth of the West Channel of the Nelson River. The Jenpeg hydroelectric generating station serves as the Lake Winnipeg control structure. Under natural conditions the West Channel carries between 80% and 85% of the discharge from Lake Winnipeg with the remaining 15% to 20% passing down

the East Channel. The flow in the East Channel represents energy lost as the water bypasses the Jenpeg power generating facility. To capture some of this lost energy, Manitoba Hydro is investigating the feasibility of constructing a control structure on the East Channel at Sea River Falls which would reduce the amount of Lake Winnipeg discharge that flows down the East Channel.

The average level of Lake Winnipeg will rise by approximately one foot after regulation is effected. The altered Lake Winnipeg water level regime will cause more water to flow through the East Channel than under present conditions providing, of course, that the East Channel remains uncontrolled. For instance, the average annual flow in the East Channel would be about 12,000 cfs if the Lake Winnipeg regulation works were not built and will be about 14,600 cfs when Lake Winnipeg is regulated. In summer (May-October) the average East Channel flow would be about 15,500 cfs without regulation and will be approximately 18,200 cfs with regulation. In winter (November-April) the average East Channel flow would be approximately 8300 cfs without regulation compared to 10,900 cfs with regulation.

The Lake Winnipeg, Churchill and Nelson Rivers Study Board contracted the Water Resources Branch of the Manitoba Department of Mines, Resources and Environmental Management to undertake a study which would provide information on the effect of the East Channel control on water levels and flows downstream from the control structure at Sea River Falls to Pipestone Lake. The area covered by the East Channel hydraulic study is shown on Fig. 1.

This report contains the results of the Water Resources Branch's

hydraulic study. Water level and channel cross-section data, and field accommodation were provided by Manitoba Hydro. The Water Survey of Canada provided discharge information.

II - DATA AND INFORMATION

The available data and information consists of

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1. FIELD RECONNAISSANCE

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Manitoba Hydro personnel established water level gauges along the main stem of the East Channel from Norway House to Pipestone Lake in 1972. The gauges were referenced to 1968 Geodetic Survey of Canada datum (1970 revision). The gauge locations are shown on Fig. 2. Water levels were recorded on June 19, 1972, and September 7, 1972, when the total East Channel flow was 20,800 cubic feet per second, cfs, and 14,300 cfs respectively and are listed in Table 1.

3. DISCHARGE MEASUREMENTS

The Water Survey of Canada metered the discharge at the six locations shown on Fig. 3. The measurements were made on June 13 and 14, 1973, when the total East Channel discharge was metered to be 13,550 cfs. The measurements are listed in Table 2. It should be noted that the discharge measurements were made at approximately the same time as the field reconnaissance.

4. MAPPING AND AERIAL PHOTOGRAPHY

The 1:50,000 national topographic series maps (map sheet 63-I/5), the 1946 and 1966 aerial photographs (1 inch = 4 miles), and the aerial photograph mosaics cover the East Channel area to the west of the Principal Meridian only (Fig. 1). The 1:250,000 national topographic

series mapping (map sheet 63-I) and the 1955 aerial photographs (1 inch = 1 mile) cover the entire East Channel study area.

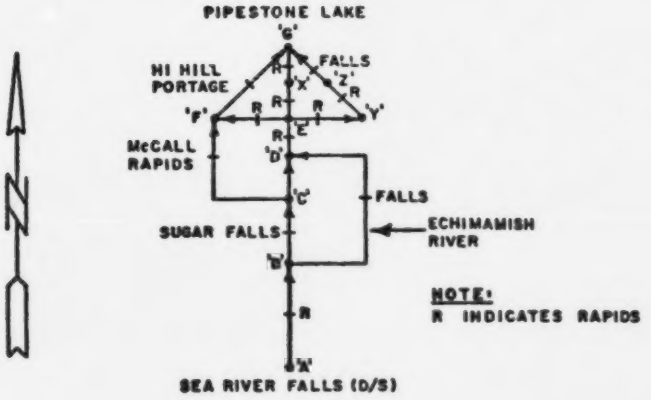
III - CALCULATIONS

The data that are available are inadequate to undertake an accurate evaluation of the hydraulic characteristics of the East Channel. Therefore, the following three basic assumptions were necessary.

1. All channel control sections, rapids and falls, acted as broad crested weirs.
2. The "Echimamish Loop", the branch of the East Channel that divides at The High Rock and picks up the Echimamish River flow, is controlled at one section below the mouth of the Echimamish River.
3. The distribution of flow in the many branches of the East Channel as metered by Water Survey of Canada with a total flow of 13,550 cfs is identical at flows of 14,300 cfs and 20,800 cfs, the two discharges at which water level measurements were made by Manitoba Hydro field staff.

The East Channel was represented schematically, as shown below, to simplify the calculating procedure.

SCHEMATIC DIAGRAM OF THE EAST CHANNEL



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The ratio of the flows in each of the metered channels, as modified and noted above, to the total measured East Channel flow was assumed

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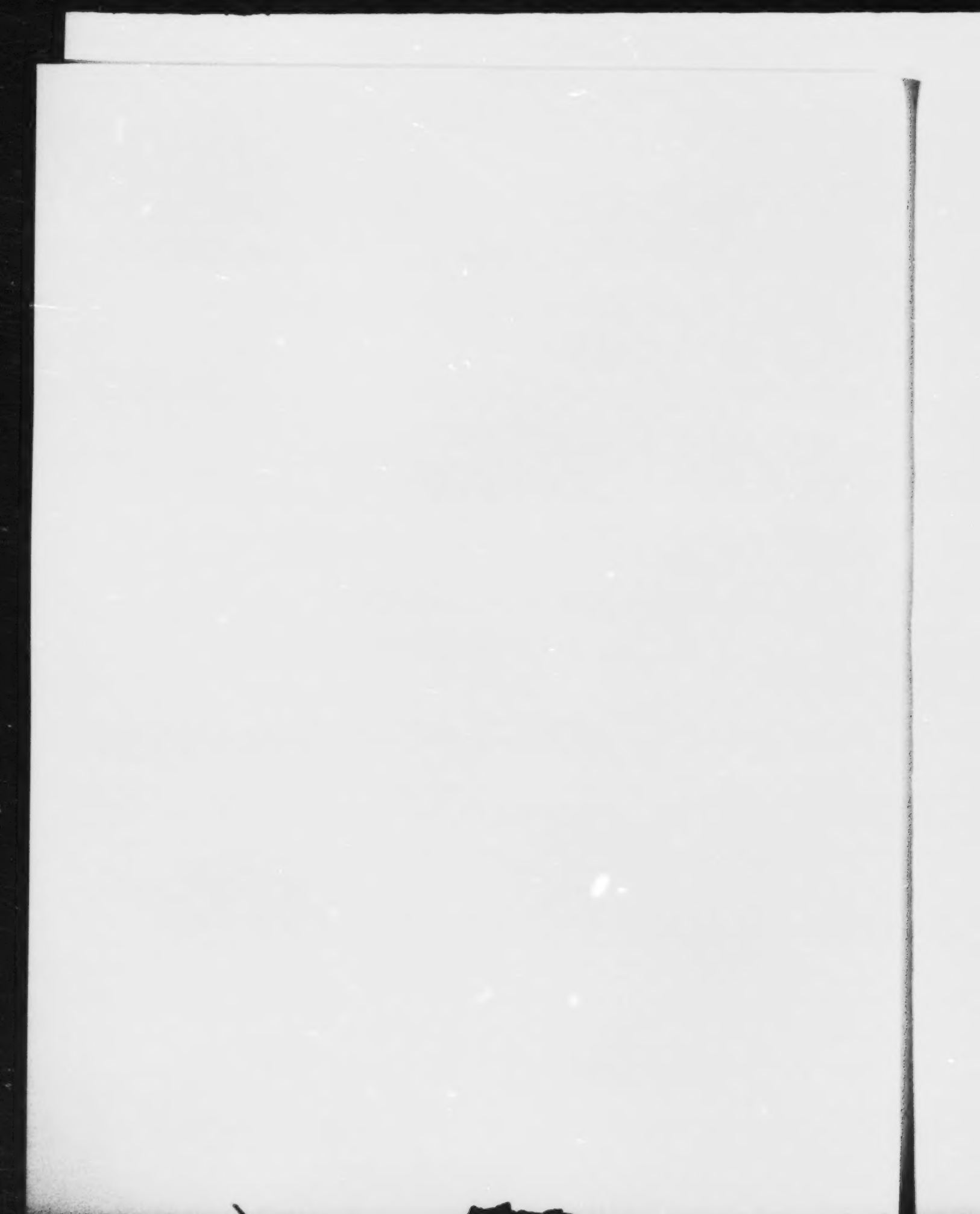

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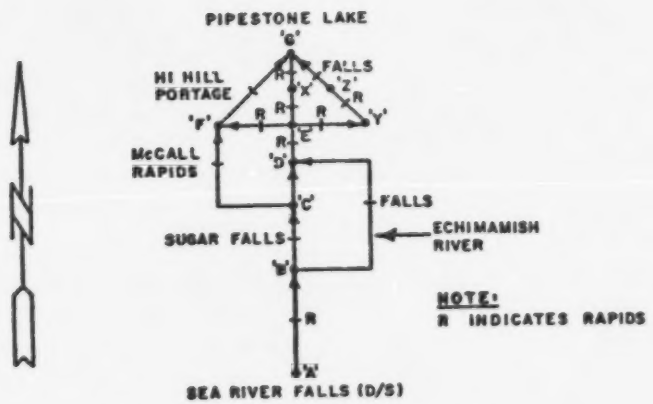

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The ratio of the flows in each of the metered channels, as modified and noted above, to the total measured East Channel flow was assumed

to apply to the East Channel flows of 14,300 cfs and 20,800 cfs, the two discharges when the water surface profiles were measured by Manitoba Hydro staff. The computed discharges for each channel are listed in Table 2 for total flows of 14,300 cfs and 20,800 cfs.

The water surface elevations at each of the points in the schematic diagram were either measured by Manitoba Hydro field staff or were interpolated from the Manitoba Hydro field measurements and from observations made during the field trip. With these two sets of discharge and water level information defined, one for a total East Channel flow of 14,300 cfs and one for 20,800 cfs, discharge to water level rating curves were prepared for each of the channels and for the points denoted on the schematic diagram. The rating curves for the points are shown on Fig. 4 and the rating curves for the channels are shown on Fig. 5. The discharge to water level rating curves were computed by assuming that each of the control sections (rapids or falls) were broad crested weirs. Therefore, the broad crested weir equation was applied.

$$Q = K(E-h)^{3/2}$$

where Q = discharge in cfs

K = constant

E = water surface elevation in feet

h = bottom or lip of the control section in feet.

Since Q and E are known for two conditions, K and h were computed and the discharge for each water surface elevation derived.

IV - OBSERVATIONS

The East Channel of the Nelson River from Sea River Falls to Pipestone Lake is composed of a number of channels and cross channels. The percentage of the total East Channel flow in each of the many channel reaches as denoted on the schematic diagram remains constant essentially. The percentage of the total flow in

1. Reach A-B is 100%,
2. Reach B-C (Sugar Falls reach) is 80%,
3. Reach B-D (Echimamish Loop) is 20%,
4. Reach C-D is 77%,
5. Reach C-F (McCall Rapids reach) is 3%,
6. Reach D-E is 97%,
7. Reach E-F is 3%,
8. Reach E-X-G is 70%,
9. Reach E-Y-Z-G is 24%, and
10. Reach F-G (Hi Hill Portage reach) is 6%.

For the sake of clarity, the observations are described by reach as referenced in the schematic diagram. The field observations were made when the total East Channel flow was approximately 13,550 cfs.

1. REACH A-B

Reach A-B extends from Sea River Falls to The High Rock. Photograph 1 shows the main section at Sea River Falls. The channel in this reach is relatively wide, 1000 feet to 2000 feet with many islands and shoals. The current is swift, perhaps two or three feet per second, but not rapid except for one area which is denoted as a rapid on Fig. 1. Water depths of 25 feet are common in this reach of the river. It can

be seen on Fig. 4 that as discharge drops, the control of the flow shifts from the rapids in this reach to controls at Sugar Falls and in the "Echimamish Loop", therefore, at low flows (1000 cfs), the velocity through the only rapid area in this reach will decrease as the rapids will be drowned by backwater from the control sections downstream. Thus, with low flow in the East Channel, the water level in Reach A-B will drop some three to four feet from the average annual flow condition of approximately 12,000 cfs, and some four to five feet from the average summer condition of approximately 15,500 cfs.

2. REACH B-C

Reach B-C is the reach of the East Channel containing Sugar Falls. Upstream of Sugar Falls to The High Rock, the channel is relarively uniform with small islands near Sugar Falls. The shoreline upstream of Sugar Falls is predominantly rock with trees to within a foot or two of the water's edge. The shoreline between Sugar Falls and the entrance to the McCall Rapids Channel has many border areas of shallow water supporting reed beds. The water levels upstream and downstream of Sugar Falls are represented by Point "B" and Point "C" respectively on Fig. 4. With reduced flow in the East Channel, the water level below Sugar Falls will drop more than the water level upstream; e.g. if the flow is reduced from 12,000 cfs, approximately the historic average annual flow, to 1000 cfs the water level upstream of Sugar Falls will drop approximately 2.7 feet while downstream of Sugar Falls the water level will drop about 4.4 feet. The channel upstream of Sugar Falls is relatively deep and decreases in water levels of three feet should not create any summer navigation problems; however, the downstream channel

is much shallower with many shoals especially near the entrance to the McCall Rapids Channel. A drop in water level below Sugar Falls would make summer navigation more hazardous than it is now as the existing submerged rock would be exposed.

3. REACH B-D

Reach B-D or the "Echimamish Loop" as it has been referred to in this report is by far the most complex reach identified in this study. It is relatively shallow with water depths of about ten feet being common. There are many cross channels and small bypass channels in this reach as can be seen on Fig. 1. The channel control is below the point of discharge of the Echimamish River and comprises a number of small rapids and one falls. A typical view of the channel upstream of the Echimamish River is shown on Photograph 2. Photographs 3 and 4 are pictures of typical channel sections and typical small rapids in the "Echimamish Loop" below the point of control. The Echimamish River near its mouth is about five or six feet deep and contains a heavy growth of underwater plants. A decrease in discharge in the East Channel to about 1000 cfs would cause the depth of water in the Echimamish River to drop to less than two feet at the mouth except when the Echimamish River flow is high. A decrease in flow in the lower reaches of the "Echimamish Loop" would expose many of the small rapids but the channel proper should still contain about five feet of water.

4. REACH C-D

This reach does not contain any rapids but the current is relatively fast suggesting shallow water. A drop in water level of four to five feet in this reach can be expected if the total East Channel flow

decreases from the average annual flow of 12,000 cfs to about 1000 cfs. A drop in water level of four or five feet would certainly make summer navigation hazardous in this reach particularly to motor boats. The shoreline in this reach is very similar to the reach of river below Sugar Falls as the shoreline is interspersed with rock outcrops and reed bed areas.

5. REACH C-F

Reach C-F is the McCall Rapids reach of the East Channel and is part of the marked navigation or canoe route. The channel in the McCall Rapids reach is relatively narrow (200 to 300 feet) and the shoreline is predominantly rock. The main section of McCall Rapids can be seen on Photograph 5. A passageway to accommodate boats is shown on the right (West) side of the picture. Photograph 6 is a typical picture of this reach below McCall Rapids. On both Photographs 5 and 6, the shoreline rock appears to have been scoured. It is surmised that this "high water" mark is a result of ice being generated through McCall Rapids and building up in the immediate downstream area. The channel upstream of McCall Rapids was estimated to be generally about ten feet deep but shallow areas of only two or three feet are common. A drop in water level in this section of the reach of four or five feet corresponding to a decrease in flow to 1000 cfs would probably expose these shallow zones and tend to create relatively "quiet" (low velocity) pools between the shallow areas. Below McCall Rapids the channel is somewhat deeper and appears to be more uniform in depth, thus the effect of lower water levels would have little or no impact on navigation.

6. REACH D-E

Reach D-E is very similar to Reach C-D in that the current in the channel is relatively fast but not rapid. Reach D-E is controlled at the lower end by a wide rapid which is broken by three islands. Lower water levels in this reach would probably create the same hazardous boating conditions foreseen in Reach C-D. The shoreline in this reach is mixed with rock outcrops and shallow water bays with reed beds.

7. REACH E-F

The control section in Reach E-F is about midway along its course, thus the water levels upstream from the controlling rapid will correspond to the water surface elevation to East Channel discharge relationship designated as Point "E" on Fig. 4, and the water levels downstream from the rapid will correspond to curve labelled Point "F" on Fig. 4. The channel in this short reach is well defined with rock outcrops generally comprising the shoreline. The channel was observed during the June, 1973, field reconnaissance to be generally ten to fifteen feet deep. Although the water level would drop about seven to eight feet if the flow were reduced to about 1000 cfs, the channel should still be navigable by boat except through the rapid reach.

8. REACH E-X-G

Reach E-X-G is the main channel discharging into Pipestone Lake. It contains two major rapid sections with about an equal drop across each. The location of these two rapids is shown on Fig. 1. Local currents in this reach of the river are relatively strong, probably three to four feet per second in some areas, with many cross currents and turbulence.

The local high velocity and turbulent nature of the flow suggests an irregular channel bottom with some shallow areas, less than five feet deep. A discharge decrease from 13,550 cfs to 1000 cfs will cause the water level to drop about eight feet in this reach which would probably expose the channel bottom in the many shallow areas. The shoreline in this reach is typical of the main portion of the East Channel, rock outcrops intermixed with reed beds. The two rapids in this reach do not have the sharply defined drop as in most other rapids in the East Channel but are longer and more spread out.

9. REACH E-Y-Z-G

Reach E-Y-Z-G is the eastern arm of the East Channel that discharges into Pipestone Lake. There are two rapid sections and one fall in this reach. Moving downstream from Point "E", as shown in the schematic diagram, the first set of rapids encountered are relatively mild with about a one-foot drop across them. The second set of rapids is larger with about a three to four-foot local drop. The falls in the lower part of this reach are much more dramatic, the majority of the water shoots through a narrow gorge with the remainder passing over a rapid section. The drop across this section was estimated to be approximately eight to nine feet. The shoreline in this reach varies from predominantly rock in the lower part to mixed rock and reed beds in the upper portion. The channel in general did not appear to be very deep, perhaps ten feet. A total East Channel flow reduced to 1000 cfs could create hazardous boating conditions upstream of the falls. Downstream from the falls the water level is controlled by Pipestone Lake, thus there would be little change from present conditions.

10. REACH F-G

Reach F-G, the Hi Hill Portage reach, upstream from Hi Hill Portage is very similar to the McCall Rapids reach in that the channel is well defined with predominantly rock shorelines. The channel upstream of Hi Hill Portage was estimated to be about ten feet deep and no shallow areas were encountered during the field trip. The rapid at Hi Hill Portage is shown on Photograph 7. As can be seen on Photograph 7, the rapid is relatively long and the water is turbulent as it passes through the narrow gorge. As at McCall Rapids, it appears that ice is probably built up below the rapid creating some bank scouring. Water levels upstream of the controlling rapid will follow the curve designated as Point "F" on Fig. 4. With flow in the East Channel reduced to 1000 cfs, it is estimated that only 60 cfs will pass through this reach. At the time that Photograph 7 was taken, approximately 800 cfs were passing through this channel. Below Hi Hill Portage, the water levels are essentially the same as Pipestone Lake and as such are controlled by the total Nelson River flow, both East and West channels. The reach below Hi Hill Portage broadens and the shoreline changes noticeably from rock to areas of shallow water vegetation.

11. PIPESTONE LAKE

The immediate offshore area in Pipestone Lake in the vicinity of the mouth of the East Channel is relatively shallow, about ten feet deep. The bottom is primarily sand or gravel with an abundance of underwater plant growth. Sand beaches are common along the shoreline. The arm of Pipestone Lake extending to the southeast contains large reed bed areas and is fed by a small stream that winds through these reeds.

The people that fish in this area call this stream the Pickerel River because "pickerel" (walleyed pike) apparently spawn in this river.

TABLE 1. East Channel water surface measurements

Gauge Number	Water Surface Elevations 1968 GSC Datum (1970 Revision)	
	June 19, 1972	Sept. 7, 1972
E7 (downstream from Sea River Falls	709.00	-
E5B	709.02	707.58
E5A	708.37	707.06
E5 (entrance to Echimamish Channel)	707.74	706.75
E4	707.55	706.60
E3	707.40	706.55
E3A	704.31	702.76
E3B	707.43	706.56
E2 (Sugar Falls)	707.43	706.45
E1	703.60	701.59
E13	701.48	699.82
E14	700.68	698.99
E15	701.22	699.65
E16	698.35	695.99
E17 (Pipestone Lake)	685.18	683.12
East Channel Discharge	20,800 c.f.s.	14,300 c.f.s.

NOTE: Water surface gauge locations shown on Figure 2.

TABLE 2. East Channel discharges

Metering Location	Metered Discharge c.f.s.	Comment	Modified Discharge c.f.s.	Computed Discharge	
				14,300 c.f.s.	20,800 c.f.s.
1	9,910	Slow Section	10,790	11,440	16,640
2	2,640	Fair Section	2,760	2,860	4.160
3	350	Good Section	350	430	630
4	917	Poor Section	820	860	1,250
5	9,760	Good Section	9,410	10,010	14,560
6	3,450	Good Section	3,320	4,990	3,430
Total East Channel Flow	13,550		13,550	14,300	20,800

NOTE: Metering section locations shown on Figure 3.

TABLE 3. East Channel water surface elevations

Location	Water Surface Elevation		Comment
	Q=14,300 c.f.s.	Q=20,800 c.f.s.	
A	707.58	709.02	Gauge E5B
B	706.75	707.74	Gauge E5
C	699.18	700.85	Interpolated between Gauges E13 and E14.
D	697.83	699.60	Gauge E15
E	695.99	698.35	Gauge E16
F	693.00	695.26	Estimated
G	683.12	685.18	Gauge E17
X	689.55	691.76	Estimated
Y	694.70	697.03	Estimated
Z	690.84	693.08	Estimated

NOTE: For location of points see schematic diagram in the text, page 5.

PHOTOGRAPH 1 - Main Section of Sea River Falls looking East from island where portage is located. June, 1973.

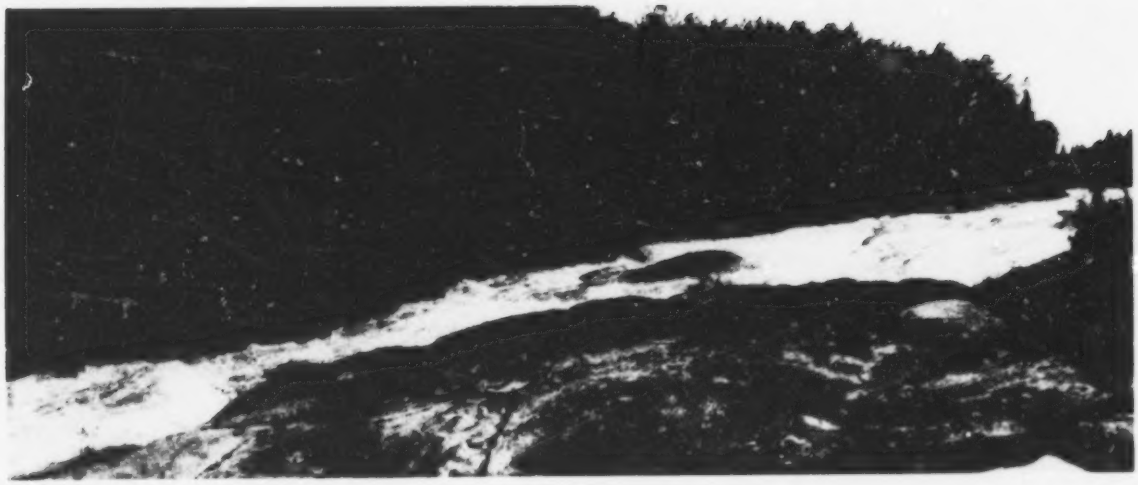
PHOTOGRAPH 2 - Typical channel section along upper portion of Echimamish Loop. June, 1973.

PHOTOGRAPH 3 - Typical section of lower portion of the Echimamish Loop. June, 1973.

PHOTOGRAPH 4 - Typical small rapid in the Echimamish Loop. June, 1973.

PHOTOGRAPH 5 - McCall Rapids. Note portage on right side of photograph. June, 1973.

PHOTOGRAPH 6 - Typical section along canoe route, the McCall Rapids reach. Note high water marks on rocks. June, 1973.



PHOTOGRAPH 7 - Hi Hill Portage. June, 1973.

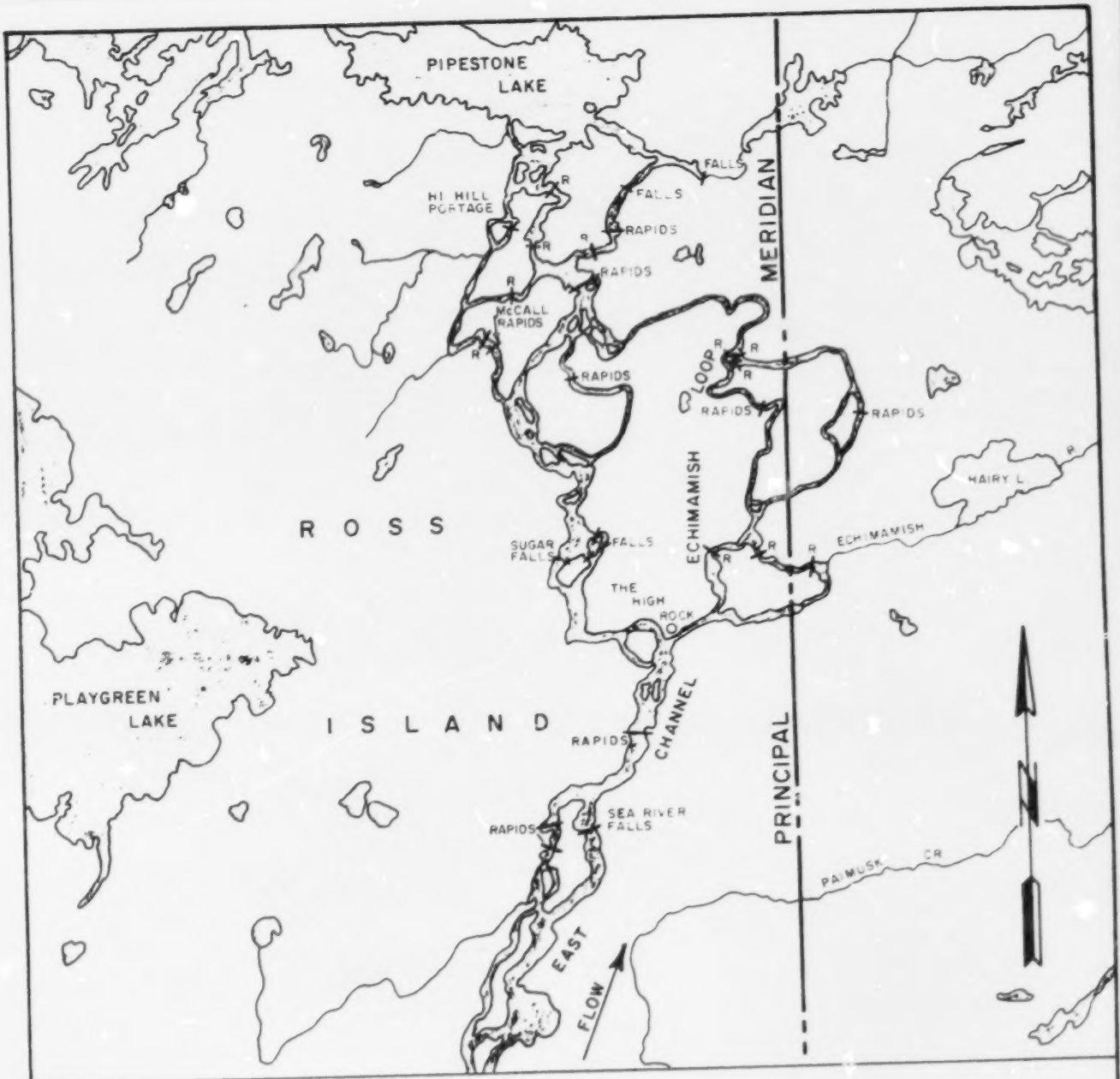


FIGURE NO. 1

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

EAST CHANNEL HYDRAULIC STUDY

STUDY AREA

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
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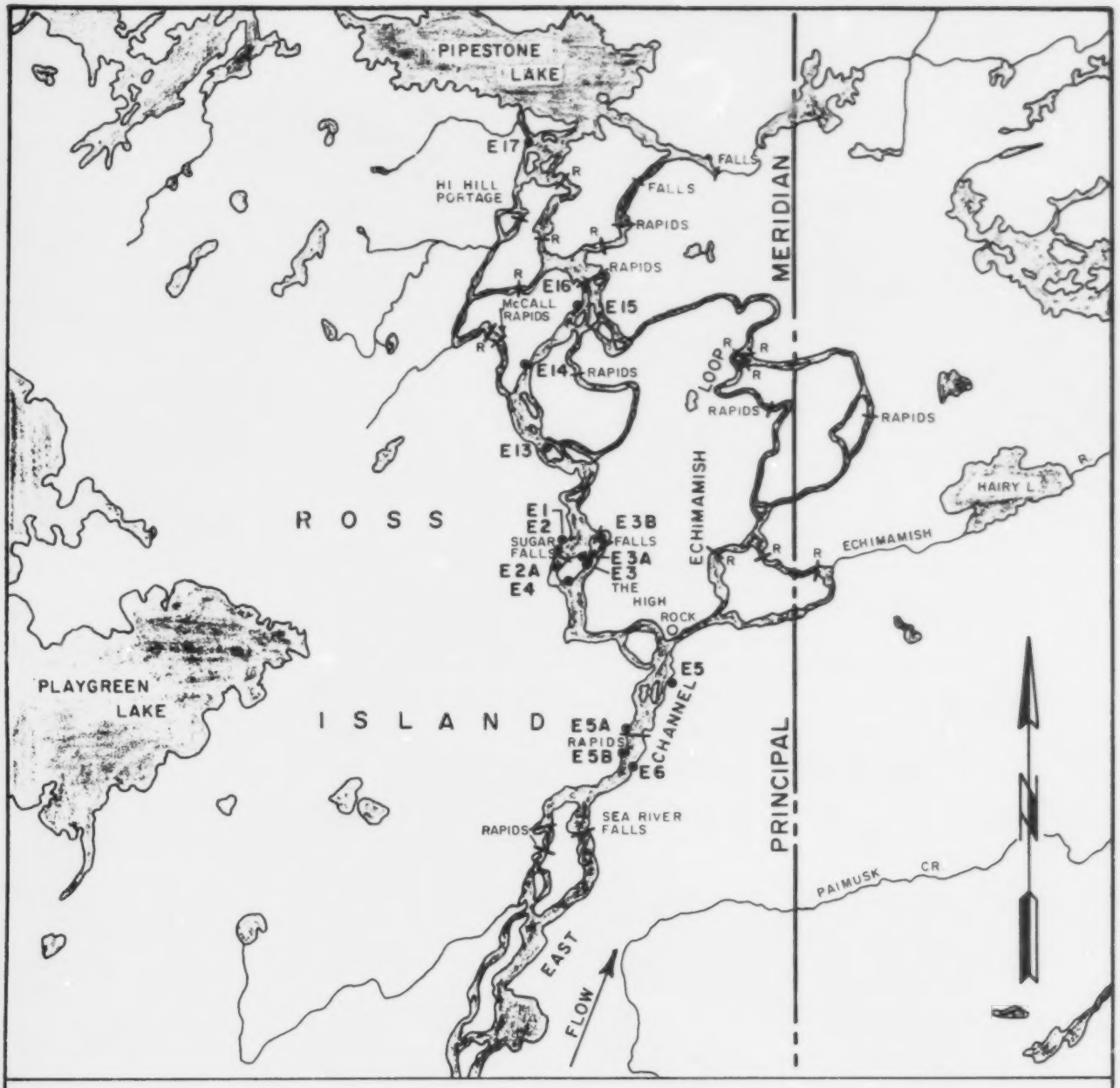
	CHECKED	DATE	DATE				



NOTE:

WATER LEVEL GAUGE LOCATIONS AND IDENTIFICATION NUMBERING SYSTEM ESTABLISHED BY MANITOBA HYDRO.

0 4 8

SCALE IN MILES

FIGURE NO. 2

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

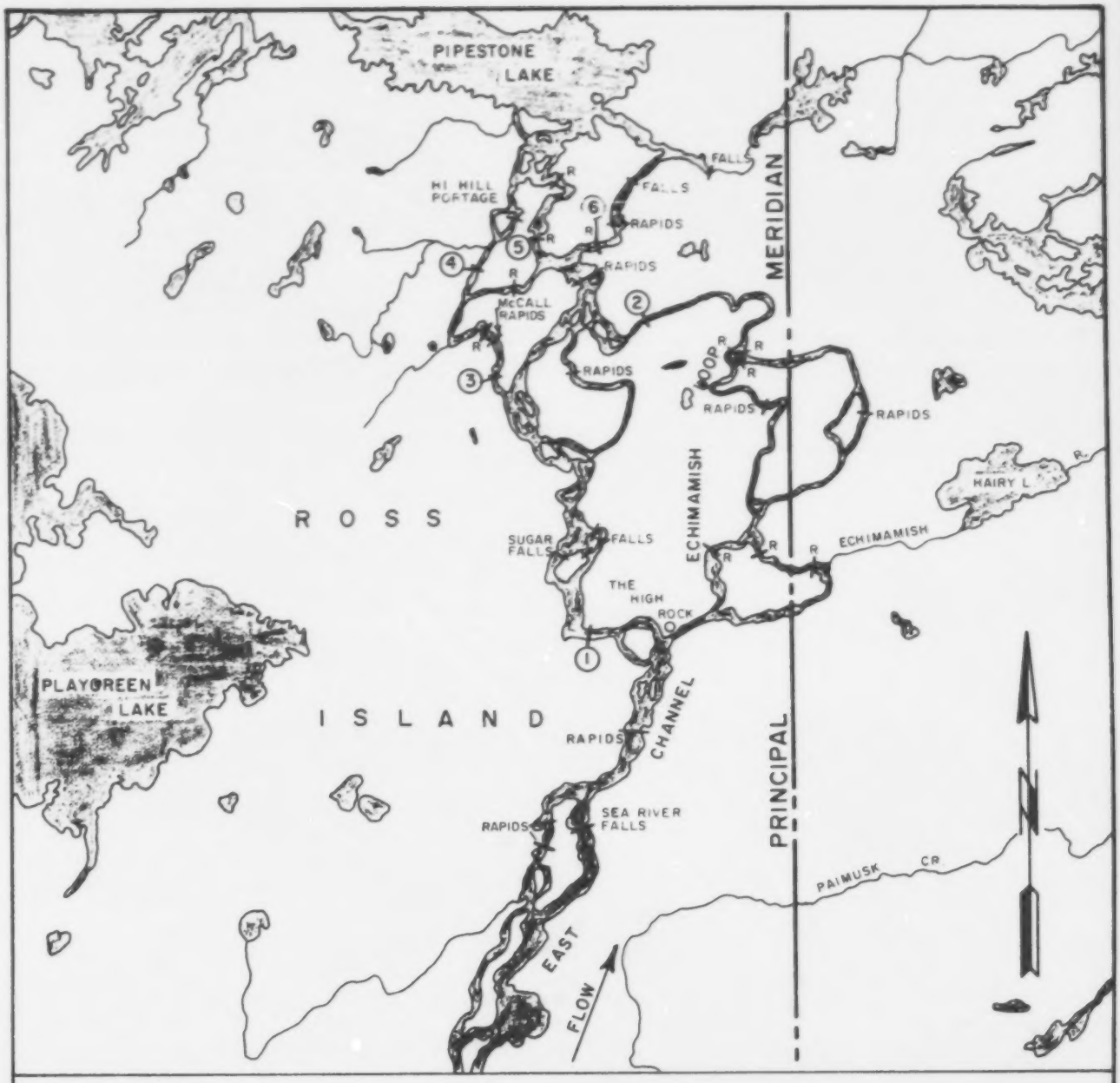
WATER RESOURCES BRANCH

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

EAST CHANNEL HYDRAULIC STUDY

WATER LEVEL GAUGE LOCATIONS

PREPARED	DRAWN	SUBMITTED	APPROVED	SCALE	DATE	SHEET	FILE NO.
D.G.R.	P.S.	DATE	DATE	AS SHOWN	OCT./73	2 of 5	51-2-1146



NOTE:

SECTIONS WERE METERED BY THE WATER SURVEY OF CANADA, DEPARTMENT OF THE ENVIRONMENT ON JUNE 13TH AND 14TH, 1973. WHEN TOTAL EAST CHANNEL FLOW WAS 13,550 C. F. S.

METERED FLOWS

Q 1 = 9,910 C. F. S.
Q 2 = 2,640 C. F. S.
Q 3 = 350 C. F. S.
Q 4 = 917 C. F. S.
Q 5 = 9,760 C. F. S.
Q 6 = 3,450 C. F. S.

0 4 8

SCALE IN MILES

FIGURE NO. 3

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

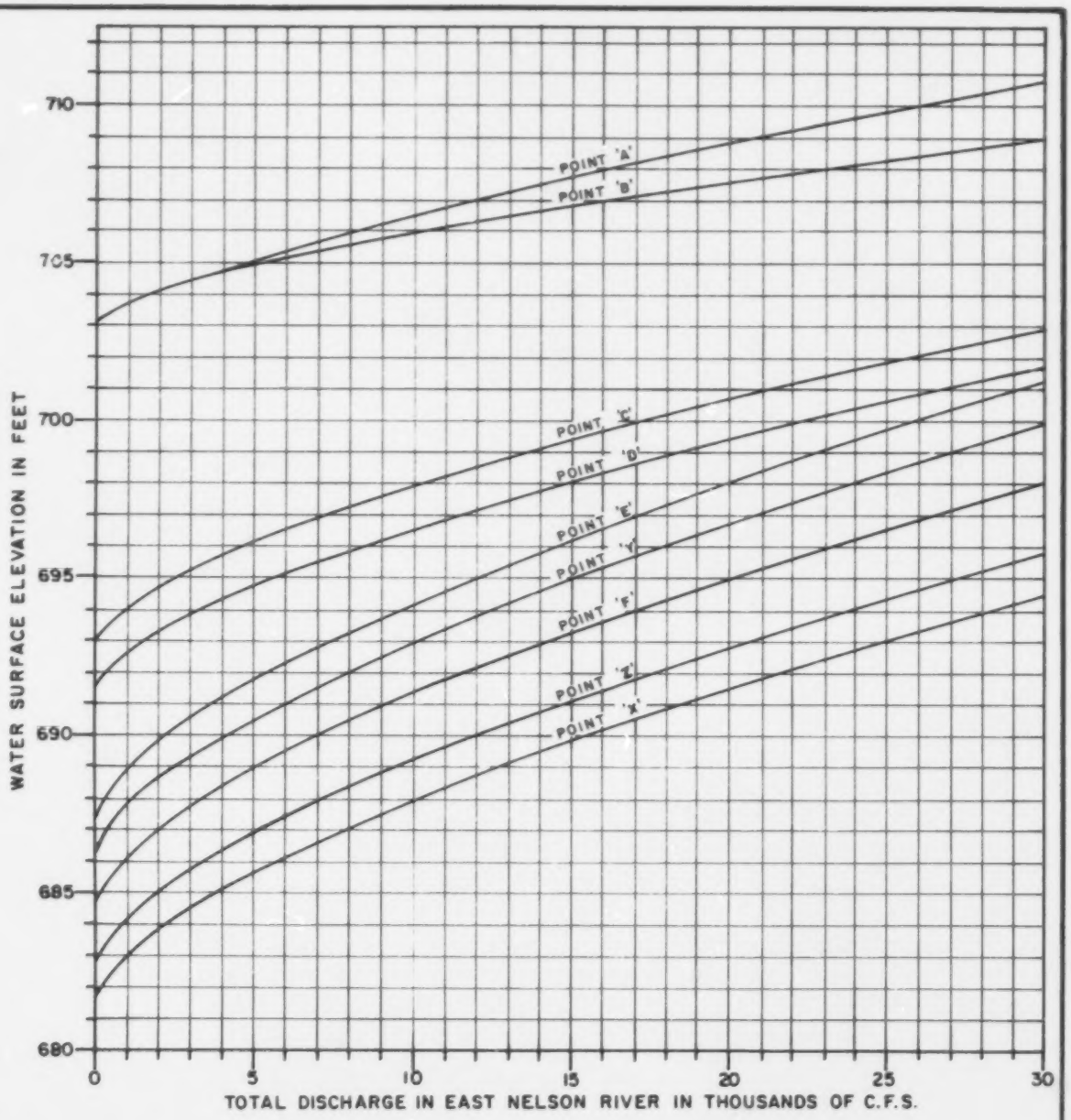
WATER RESOURCES BRANCH

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

EAST CHANNEL HYDRAULIC STUDY
DISCHARGE METERING SECTIONS

PREPARED	DRAWN	SUBMITTED	
D.G.R.	P.G.		
	CHECKED	DATE	DATE

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	OCT./73	3095	51-2-1146



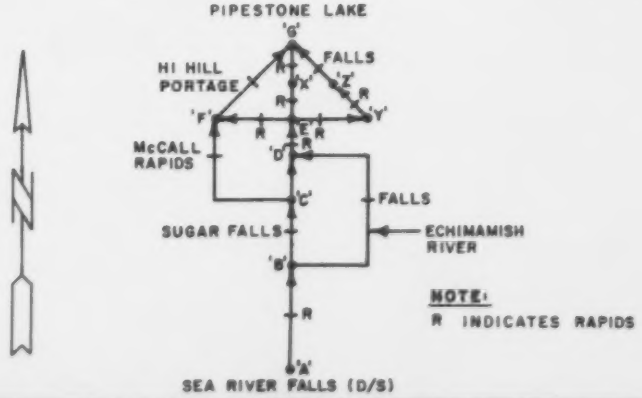


FIGURE NO. 4

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

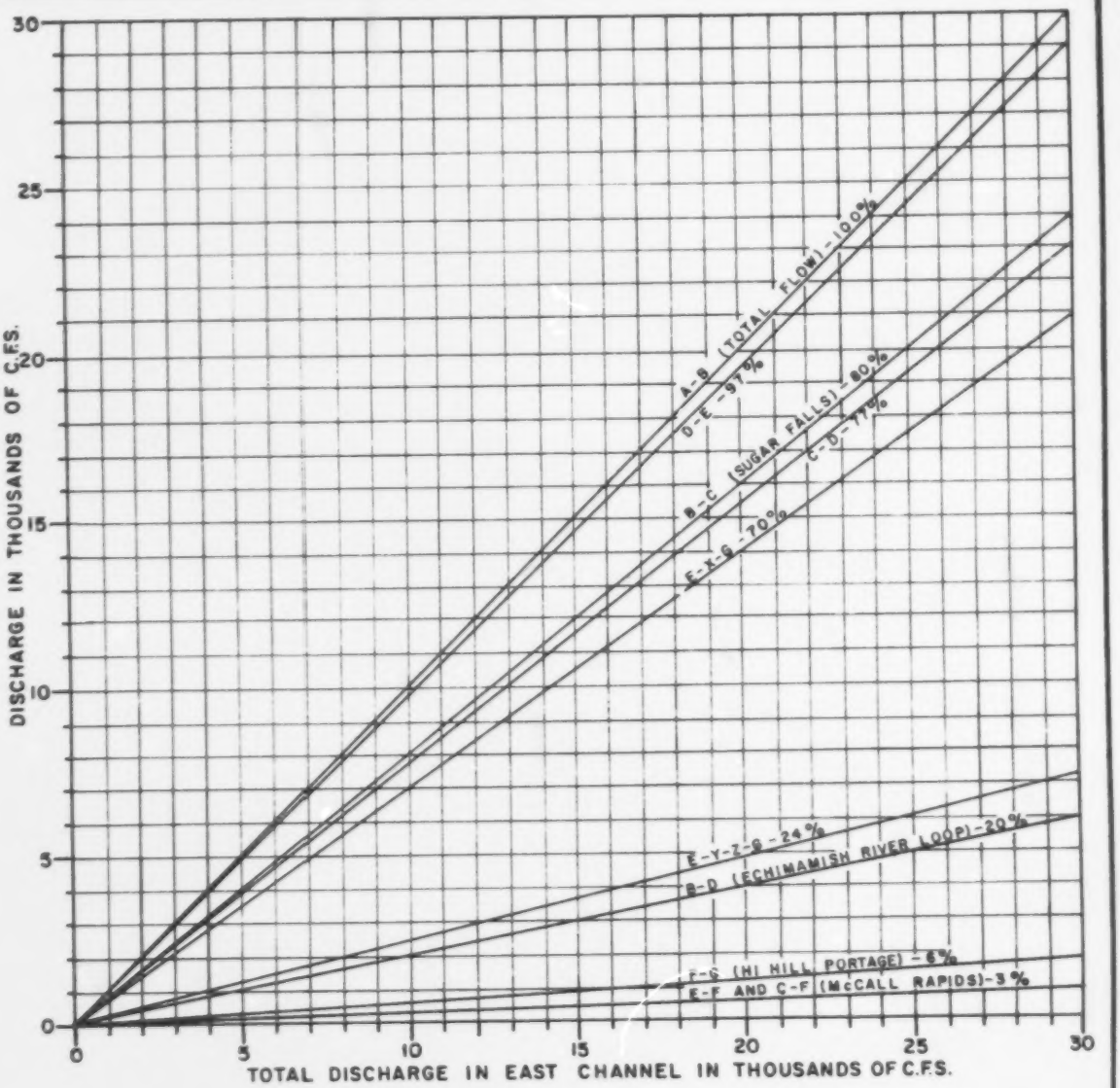
WATER RESOURCES BRANCH

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

EAST CHANNEL HYDRAULIC STUDY
RATING CURVES

PREPARED	DESIGN	CHECKED	DRAWN	CHECKED	APPROVED
D.G.R.	P.G.		DATE		DATE

SCALE	DATE	SHEET	FILE NO.
AS SHOWN	OCT./73	4895	51-2-1146


DISCHARGE IN THOUSANDS OF C.F.S.
TOTAL DISCHARGE IN EAST CHANNEL IN THOUSANDS OF C.F.S.
A-B (TOTAL FLOW) - 100%
D-E - 97%
B-C (SUGAR FALLS) - 80%
C-D - 77%
F-X-B - 70%
E-Y-Z-B - 24%
B-D (ECHIMAMISH RIVER LOOP) - 29%
F-G (HI HILL PORTAGE) - 6%
E-F AND C-F (McCALL RAPIDS) - 3%

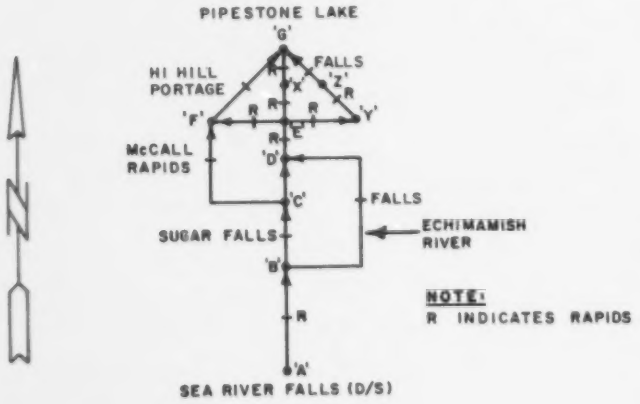


FIGURE NO. 5

PROVINCE OF MANITOBA

DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT

WATER RESOURCES BRANCH

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

EAST CHANNEL HYDRAULIC STUDY

DISCHARGE DISTRIBUTION

PREPARED	DRAWN	DESIGNED		SCALE	DATE	SHEET	FILE NO.
D. G. R.	P.S.			AS SHOWN	OCT/78	8 OF 8	51-2-1146

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

LIST OF APPENDICES

APPENDIX 1	BACKGROUND DOCUMENTS AND INTERIM REPORTS	
APPENDIX 2	HYDROLOGIC, HYDRAULIC AND GEOMORPHOLOGIC STUDIES	VOL. 1 VOL. 2
APPENDIX 3	BIOPHYSICAL, FORESTRY AND GEOLOGICAL STUDIES	
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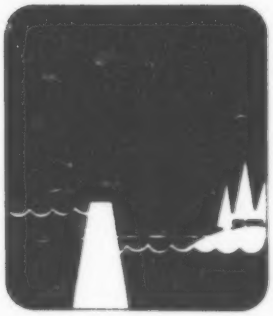
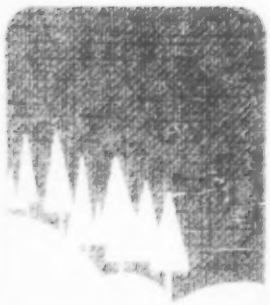
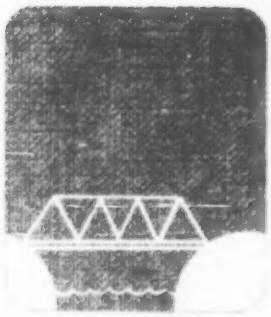
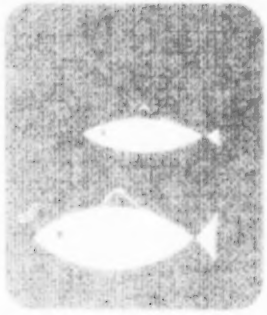
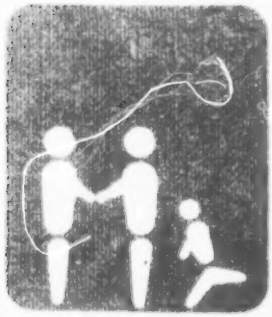
APPENDIX 7	RECREATION AND ARCHAEOLOGICAL STUDIES	
APPENDIX 8	SOCIAL AND ECONOMIC STUDIES	VOL. 1 VOL. 2 VOL. 3

* * *

Volume

2



lake winnipeg, churchill & nelson rivers study board CANADA MANITOBA 1971-75

hydrologic, hydraulic & geomorphologic studies

vol 2 technical report appendix 2

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

APPENDIX 2 - HYDROLOGIC, HYDRAULIC AND GEOMORPHOLOGIC STUDIES, VOL. 2

A - RESULTS OF WATER SAMPLING PROGRAM IN NORTHERN MANITOBA 1972-1974

B - WATER LEVEL AND FLOW INFORMATION

C - LAKE WINNIPEG SOUTH BASIN MAPPING PROJECT

D - RAT-BURNTWOOD RIVERS SYSTEM MAPPING PROJECT

RESULTS OF WATER SAMPLING PROGRAM IN NORTHERN MANITOBA 1972-1974

by

M. MORELLI
Environmental Protection Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba
February, 1975

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

STATION # 1 - WATER INTAKE TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES		
	July 6, 1972	July 31, 1972	Sept. 5, 1972
Turbidity	2.3	3.5	6.0
Temperature (Field)°C	13.3	—	—
Temperature (Lab)°C	—	—	24.4
Colour	30.	30.	70.
pH	—	8.0	7.8
Chloride (Cl) mg/l	1.6	—	3.6
Copper (Cu) mg/l	0.47	0.098	0.20
Fluoride (F) mg/l	0.07	0.13	0.06
Iron (Fe) mg/l	0.02	L 0.05	0.52
Lead (Pb) mg/l	0.006	0.043	0.006
Manganese (Mn) mg/l	L 0.010	L 0.008	0.014
Nitrogen T. Kjeldahl (N) mg/l	0.37	0.64	0.60
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	1.3	0.88
Phosphorus Total (P) mg/l	0.014	—	0.018
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	0.004
Potassium (K) mg/l	1.1	—	1.0
Non Filterable Residue, mg/l	—	1.2	4.4
Fixed Residue, mg/l	—	L 0.1	2.0
Mercury (Hg) µg/l	0.12	0.67	1.9*
Zinc (Zn) mg/l	0.01	0.008	0.012
Sodium (Na) mg/l	3.0	—	3.5
Silica (SiO_2) mg/l	0.5	—	2.2
Sulphate (SO_4) mg/l	1.1	0.8	1.0
Calcium (Ca) mg/l	—	14.4	9.9
Hardness Total ($CaCO_3$) mg/l	—	49.6	37.1
Alkalinity Total ($CaCO_3$) mg/l	—	44.0	44.9
Specific Conductance, micromho/cm	109.	101.	112.
Total Inorganic Carbon (C) mg/l	7.0	—	7.0
Total Organic Carbon (C) mg/l	11.0	—	13.0
Total Coliform (M.P.N.)	4	4	4
Fecal Coliform (M.P.N.)	—	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION# 1 - WATER INTAKE TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES Sept. 29, 1972	Nov. 1, 1972	Dec. 7, 1972
Turbidity	2.7	1.8	2.1
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	22.0	22.5	22.8
Colour	25.	10.	15.
pH	—	7.8	7.8
Chloride (Cl) mg/l	1.1	1.2	1.2
Copper (Cu) mg/l	0.77	0.025	0.043
Fluoride (F) mg/l	0.06	0.06	0.08
Iron (Fe) mg/l	L0.04	L0.04	0.04
Lead (Pb) mg/l	0.011	0.010	L0.006
Manganese (Mn) mg/l	0.003	L0.010	L0.005
Nitrogen T. Kjeldahl (N) mg/l	0.64	0.64	0.75
Nitrogen Nitrate, Nitrite (N) mg/l	0.26	L0.01	0.05
Phosphorus Total (P) mg/l	0.007	0.019	0.010
Phosphorus Ortho (P) mg/l	0.007	0.007	L0.003
Inorganic Phosphorus (P) mg/l	0.003	0.011	0.005
Potassium (K) mg/l	0.8	1.0	1.2
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.35	3.2*	1.5*
Zinc (Zn) mg/l	0.011	0.004	L0.001
Sodium (Na) mg/l	2.2	2.4	2.7
Silica (SiO_2) mg/l	1.1	1.0	1.5
Sulphate (SO_4) mg/l	3.4	3.2	3.9
Calcium (Ca) mg/l	11.2	14.1	14.4
Hardness Total ($CaCO_3$) mg/l	70.3	47.5	53.2
Alkalinity Total ($CaCO_3$) mg/l	—	46.9	49.2
Specific Conductance, micromho/cm	93.2	100.	109.
Total Inorganic Carbon (C) mg/l	7.	8.	12.
Total Organic Carbon (C) mg/l	8.	10.	8.
Total Coliform (M.P.N.)	0	0	4.
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* Doubtful Data

STATION#

CONSTITUENTS	SAMPLING DATES Dec. 27, 1972	Feb. 5, 1973	Mar. 5, 1973
Turbidity	2.5	2.6	2.5
Temperature (Field) °C	---	---	5.6
Temperature (Lab) °C	25.	25.	24.
Colour	10.	20.	20.
pH	7.8	7.1	7.9
Chlorine (Cl) mg/l	1.9	1.0	1.1
Copper (Cu) mg/l	0.049	0.054	0.058
Fluoride (F) mg/l	0.18	0.07	0.08
Iron (Fe) mg/l	0.01	0.03	0.03
Lead (Pb) mg/l	L 0.008	L 0.003	---
Manganese (Mn) mg/l	L 0.005	L 0.002	0.00
Nitrogen T. Kjeldahl (N) mg/l	0.41	0.78	0.18
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.10	0.07
Phosphorus Total (P) mg/l	0.011	0.038	0.016
Phosphorus Ortho (P) mg/l	0.005	0.005	0.00
Inorganic Phosphorus (P) mg/l	0.005	0.005	0.008
Potassium (K) mg/l	1.2	1.3	1.2
Non Filterable Residue, mg/l	---	---	---
Fixed Residue, mg/l	---	---	---
Mercury (Hg) µg/l	0.25	0.18	1.0
Zinc (Zn) mg/l	0.001	L 0.002	0.00
Sodium (Na) mg/l	2.6	2.9	3.0
Silica (SiO_2) mg/l	2.0	3.0	3.4
Sulphate (SO_4) mg/l	5.7	4.3	3.9
Calcium (Ca) mg/l	16.2	14.8	18.2
Hardness Total ($CaCO_3$) mg/l	58.5	54.6	58.2
Alkalinity Total ($CaCO_3$) mg/l	48.2	50.0	50.6
Specific Conductance, microMho/cm	105.	107.	105.
Total Inorganic Carbon (C) mg/l	11.	12.	12.
Total Organic Carbon (C) mg/l	8.	7.	7.
Total Coliform (M.P.N.)	4.	0.	0.
Fecal Coliform (M.P.N.)	4.	0.	0.

LEGEND M'N = Most probable number per 100 ml

L = less than

STATION # 1 - WATER INTAKE, TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES Apr. 6, 1973	May 3, 1973	May 29, 1973
Turbidity	2.8	3.3	9.4
Temperature (Field) °C	---	6.1	---
Temperature (Lab) °C	24.5	---	24.8
Colour	20.	25.	40.
pH	7.8	---	7.8
Chloride (Cl) mg/l	1.5	---	1.2
Copper (Cu) mg/l	0.034	0.044	0.043
Fluoride (F) mg/l	0.09	0.08	0.06
Iron (Fe) mg/l	0.05	0.06	L 0.05
Lead (Pb) mg/l	---	L 0.006	L 0.006
Manganese (Mn) mg/l	L 0.008	L 0.006	L 0.00[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.39	0.13	0.3[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.28	0.18
Phosphorus Total (P) mg/l	0.012	0.011	0.012
Phosphorus Ortho (P) mg/l	0.004	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.007	0.007	L 0.00[illegible]
Potassium (K) mg/l	1.3	---	0.7
Non Filterable Residue, mg/l	---	---	6.4
Fixed Residue, mg/l	---	---	1.2
Mercury (Hg) µg/l	0.15	0.02	0.05
Zinc (Zn) mg/l	L 0.002	0.002	L 0.003
Sodium (Na) mg/l	2.7	---	2.0
Silica (SiO_2) mg/l	3.4	---	2.6
Sulphate (SO_4) mg/l	3.4	7.8	3.7
Calcium (Ca) mg/l	14.6	---	13.2
Hardness Total ($CaCO_3$) mg/l	50.6	---	45.9
Alkalinity Total ($CaCO_3$) mg/l	---	---	44.8
Specific Conductance, micromho/cm	108.	108.	85.
Total Inorganic Carbon (C) mg/l	9.	9.	7.
Total Organic Carbon (C) mg/l	9.	8.	8.
Total Coliform (M.P.N.)	4.	0.	23.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 1 - WATER INTAKE, TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES July 3, 1973	Aug. 8, 1973	Sept. 10, 1973
Turbidity	3.8	3.2	2.1
Temperature (Field) °C	5.5	17.2	---
Temperature (Lab) °C	24.8	24.3	22.0
Colour		10.	20.
pH	8.0	7.7	7.9
Chloride (Cl) mg/l	1.1	0.9	1.5
Copper (Cu) mg/l	0.021	0.019	0.030
Fluoride (F) mg/l	0.09	0.07	0.07
Iron (Fe) mg/l	L 0.04	L 0.04	0.03
Lead (Pb) mg/l	L 0.002	L 0.004	L 0.009
Manganese (Mn) mg/l	L 0.011	L 0.008	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	0.35	---	---
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.38	0.31
Phosphorus Total (P) mg/l	0.007	0.008	---
Phosphorus Ortho (P) mg/l	L 0.003	0.003	---
Inorganic Phosphorus (P) mg/l	---	0.003	---
Potassium (K) mg/l	1.0	0.9	1.0
Non Filterable Residue, mg/l	---	---	---
Fixed Residue, mg/l	---	---	---
Mercury (Hg^{++}) µg/l	0.12	0.10	0.08
Zinc (Zn) mg/l	L 0.003	L 0.001	0.003
Sodium (Na) mg/l	2.5	2.6	2.7
Silica (SiO_2) mg/l	1.2	1.6	2.1
Sulphate (SO_4) mg/l	2.8	2.8	1.6
Calcium (Ca) mg/l	15.	16.	13.
Hardness Total ($CaCO_3$) mg/l	49.	45.	42.
Alkalinity Total ($CaCO_3$) mg/l	48.	44.	43.
Specific Conductance, micromho/cm	103.	90.	87.
Total Inorganic Carbon (C) mg/l	8.	10.	10.
Total Organic Carbon (C) mg/l	26.	6.	5.
Total Coliform (M.P.N.)	L 240.	---	0.
Fecal Coliform (M.P.N.)	---	---	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 1 - WATER INTAKE, TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES Oct. 2, 1973	Oct. 30, 1973	Dec. 12, 1973
Turbidity	2.0	3.2	1.8
Temperature (Field) °C	---	---	---
Temperature (Lab) °C	20.6	23.0	10.2
Colour	10.	20.	15.
pH	7.6	7.5	7.8
Chloride (Cl) mg/l	1.1	1.3	2.1
Copper (Cu) mg/l	0.017	L 0.005	0.041
Fluoride (F) mg/l	0.09	---	0.09
Iron (Fe) mg/l	L 0.04	---	L 0.04
Lead (Pb) mg/l	0.005	---	0.004
Manganese (Mn) mg/l	0.031	---	L 0.01
Nitrogen T. Kjeldahl (N) mg/l	0.4	---	0.2
Nitrogen Nitrate, Nitrite (N) mg/l	0.01	---	0.01
Phosphorus Total (P) mg/l	0.007	0.044	L 0.003
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.004	L 0.003	L 0.003
Potassium (K) mg/l	0.9	0.8	1.2
Non Filterable Residue, mg/l	---	---	---
Fixed Residue, mg/l	---	---	---
Mercury (Hg) µg/l	0.06	L 0.04	0.40
Zinc (Zn) mg/l	0.047	---	0.002
Sodium (Na) mg/l	2.4	2.1	2.9
Silica (SiO_2) mg/l	1.8	1.8	2.6
Sulphate (SO_4) mg/l	0.4	2.4	2.8
Calcium (Ca) mg/l	14.	12.	15.
Hardness Total ($CaCO_3$) mg/l	45.	46.	43.
Alkalinity Total ($CaCO_3$) mg/l	42.	42.	41.
Specific Conductance, micromho/cm	88.	86.	88.
Total Inorganic Carbon (C) mg/l	9.	8.	10.
Total Organic Carbon (C) mg/l	7.	8.	6.
Total Coliform (M.P.N.)	9.	0.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 1 - WATER INTAKE, TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES Jan. 7, 1974	Feb. 4, 1974	Mar. 6, 1974
Turbidity	2.8	2.2	2.8
Temperature (Field) °C	---	3.3	---
Temperature (Lab) °C	15.6	15.9	15.8
Colour	15.	15.	15.
pH	7.4	7.4	7.7
Chloride (Cl) mg/l	1.2	2.1	1.3
Copper (Cu) mg/l	0.018	0.034	0.028
Fluoride (F) mg/l	0.09	0.07	0.06
Iron (Fe) mg/l	L 0.04	L 0.04	L 0.04
Lead (Pb) mg/l	L 0.004	L 0.003	0.003
Manganese (Mn) mg/l	L 0.008	L 0.02	L 0.02
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.4	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.07	0.07
Phosphorus Total (P) mg/l	0.011	0.008	0.009
Phosphorus Ortho (P) mg/l	L 0.003	0.003	0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.003	0.006
Potassium (K) mg/l	1.1	1.0	1.1
Non Filterable Residue, mg/l	---	---	---
Fixed Residue, mg/l	---	---	---
Mercury (Hg) µg/l	0.08	---	L 0.04
Zinc (Zn) mg/l	0.002	L 0.002	L 0.001
Sodium (Na) mg/l	2.6	2.8	3.4
Silica (SiO_2) mg/l	2.9	2.9	3.0
Sulphate (SO_4) mg/l	3.1	2.1	2.5
Calcium (Ca) mg/l	12.	13.	14.
Hardness Total ($CaCO_3$) mg/l	42.	44.	50.
Alkalinity Total ($CaCO_3$) mg/l	44.	45.	48.
Specific Conductance, micromho/cm	89.	95.	106.
Total Inorganic Carbon (C) mg/l	9.	10.	11.
Total Organic Carbon (C) mg/l	7.	8.	8.
Total Coliform (M.P.N.)	4.	L 240.	0.
Fecal Coliform (M.P.N.)	0.	---	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 1

Water Intake,
Townsite of Churchill

CONSTITUENTS	SAMPLING DATES April 3/74	May 3/74	June 5/74
Turbidity	2.0	2.0	14.
Temperature (Field)°C			
Temperature (Lab)°C	20.2	22.5	23.1
Colour	15.	40.	30.
pH	7.5	7.8	7.8
Chloride (Cl) mg/l	1.2	1.2	1.5
Copper (Cu) mg/l	0.43	0.059	0.032
Fluoride (F) mg/l	0.08	0.09	< 0.05
Iron (Fe) mg/l	< 0.03	0.07	< 0.040
Lead (Pb) mg/l	0.004	0.004	0.005
Manganese (Mn) mg/l	< 0.008	< 0.010	< 0.010
Nitrogen T. Kjeldahl (N) mg/l	-	0.5	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.19	0.18
Phosphorus Total (P) mg/l	0.009	0.014	0.031
Phosphorus Ortho (P) mg/l	0.003	< 0.003	< 0.003
Inorganic Phosphorus (P) mg/l	0.003	< 0.003	0.003
Potassium (K) mg/l	1.2	1.1	1.0
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	< 0.03	0.12	< 0.05
Zinc (Zn) mg/l	0.003	0.001	0.003
Sodium (Na) mg/l	3.4	3.0	2.7
Silica (SiO_2) mg/l	3.0	2.8	1.5
Sulphate (SO_4) mg/l	2.8	3.4	3.1
Calcium (Ca) mg/l	12.2	17.	13.
Hardness Total ($CaCO_3$) mg/l	49.8	54.	45.
Alkalinity Total ($CaCO_3$) mg/l	51.	52.	47.
Specific Conductance, micromho/cm	110.	117.	100.
Total Inorganic Carbon (C) mg/l	12.	10.	10.
Total Organic Carbon (C) mg/l	9.	11.	10.
Total Coliform (M.P.N.)		0.	0.
Fecal Coliform (M.P.N.)		0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 1 WATER INTAKE: TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES July 3, 1974	July31, 1974	September 5, 1974
Turbidity	1.7	1.7	
Temperature (Field) °C	—	—	7.7
Temperature (Lab) °C	23.6	21.5	
Colour	10.	L5.	
pH	7.6	7.7	
Chloride (Cl) mg/l	1.9	--	
Copper (Cu) mg/l	0.019	0.038	0.054
Fluoride (F) mg/l	0.08	0.08	
Iron (Fe) mg/l	0.060	L0.04	0.23
Lead (Pb) mg/l	L0.004	L0.004	0.005
Manganese (Mn) mg/l	0.030	L0.01	0.016
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	0.09	L0.01	0.3
Phosphorus Total (P) mg/l	0.013	0.006	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	
Potassium (K) mg/l	1.1	—	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) µg/l	0.43	--	
Zinc (Zn) mg/l	0.003	0.002	0.007
Sodium (Na) mg/l	3.2	--	
Silica (SiO_2) mg/l	1.4	--	
Sulphate (SO_4) mg/l	2.7	5.7	
Calcium (Ca) mg/l	14.	14.	
Hardness Total ($CaCO_3$) mg/l	54.4	49.	
Alkalinity Total ($CaCO_3$) mg/l	51.	55.	
Specific Conductance, micromho/cm	114.	110.	
Total Inorganic Carbon (C) mg/l	12.	9.	
Total Organic Carbon (C) mg/l	7.	7.	
Total Coliform (M.P.N.)	9.	0.	
Fecal Coliform (M P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 1 WATER INTAKE TOWNSITE OF CHURCHILL

CONSTITUENTS	SAMPLING DATES 19/9/74	7/10/74	5/10/74
Turbidity	0.9	1.9	4.3
Temperature (Field)°C	7.2	7.0	5.6
Temperature (Lab)°C	23.1	20.0	18.2
Colour	10.	5.	L5.
pH	8.0	8.0	7.9
Chloride (Cl) mg/l	1.5	1.2	1.2
Copper (Cu) mg/l	0.065	0.026	0.030
Fluoride (F) mg/l	0.06	L0.05	0.08
Iron (Fe) mg/l	L0.04	L0.04	L0.04
Lead (Pb) mg/l	0.009	0.004	L0.004
Manganese (Mn) mg/l	L0.01	0.016	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.4	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	L0.01	0.02	
Phosphorus Total (P) mg/l	0.006	0.008	0.016
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	L0.003
Potassium (K) mg/l	1.1	1.1	1.1
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) microgram/l	0.12	0.13	L0.05
Zinc (Zn) mg/l	0.003	0.003	0.003
Sodium (Na) mg/l	3.1	3.0	3.1
Silica (SiO_2) mg/l	1.4	1.9	2.2
Sulphate (SO_4) mg/l	3.2	2.8	2.9
Calcium (Ca) mg/l	16	13	15
Hardness Total ($CaCO_3$) mg/l	48	48	50
Alkalinity Total ($CaCO_3$) mg/l	50	48	50
Specific Conductance, micromho/cm	100	106	106
Total Inorganic Carbon (C) mg/l	11	19	12
Total Organic Carbon (C) mg/l	5	12	8
Total Coliform (M.P.N.)	0	0	
Fecal Coliform (M.P.N.)	--	0	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #2 - LITTLE BEAVER RIVER NEAR MOUTH

CONSTITUENTS	SAMPLING DATES June 26, 1972	August 23/72	October 2/72
Turbidity	2.0	1.8	2.9
Temperature (Field) °C	50.	—	—
Temperature (Lab) °C	24.7	23.0	22.0
Colour	70.	70.	60.
pH	7.4	7.8	7.9
Chloride (Cl) mg/l	0.9	1.0	1.4
Copper (Cu) mg/l	0.003	0.001	0.003
Fluoride (F) mg/l	L 0.05	L 0.05	L 0.05
Iron (Fe) mg/l	0.06	0.05	0.14
Lead (Pb) mg/l	L 0.004	L 0.006	L 0.00
Manganese (Mn) mg/l	L 0.010	L 0.02	0.02
Nitrogen T. Kjeldahl (N) mg/l	--	0.14	0.2
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	L 0.01	0.9
Phosphorus Total (P) mg/l	—	0.012	0.02
Phosphorus Ortho (P) mg/l	0.003	0.004	0.00
Inorganic Phosphorus (P) mg/l	0.007	0.007	0.00
Potassium (K) mg/l	0.4	0.3	0.3
Non Filterable Residue, mg/l	—	—	--
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	L 0.04	0.53
Zinc (Zn) mg/l	0.002	L 0.001	0.002
Sodium (Na) mg/l	1.1	1.3	1.7
Silica (SiO_2) mg/l	1.2	2.3	1.9
Sulphate (SO_4) mg/l	1.1	2.1	3.9
Calcium (Ca) mg/l	17.3	18.4	19.6
Hardness Total ($CaCO_3$) mg/l	49.9	61.6	58.1
Alkalinity Total ($CaCO_3$) mg/l	44.9	56.1	50.2
Specific Conductance, micromho/cm	95.4	111.	116.
Total Inorganic Carbon (C) mg/l	9.	9.	8.
Total Organic Carbon (C) mg/l	14.	16.	14.
Total Coliform (M.P.N.)	--	23.	23.
Fecal Coliform (M.P.N.)	—	9.	4.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 2 LITTLE BEAVER RIVER NEAR MOUTH

CONSTITUENTS	SAMPLING DATES Mar. 1, 1973	Mar. 31, 1973	May 28, 1973
Turbidity	3.4	2.7	2.6
Temperature (Field) °C	32.	—	—
Temperature (Lab) °C	23.2	22.0	24.0
Colour	55.	60.	50.
pH	8.2	8.0	7.8
Chloride (Cl) mg/l	2.6	2.1	1.0
Copper (Cu) mg/l	0.003	L 0.003	0.00[illegible]
Fluoride (F) mg/l	0.08	0.07	L 0.05
Iron (Fe) mg/l	0.46	0.51	0.12
Lead (Pb) mg/l	—	L 0.004	L 0.004
Manganese (Mn) mg/l	0.008	0.013	L 0.00[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.97	0.69	--
Nitrogen Nitrate, Nitrite (N) mg/l	0.23	0.18	0.04
Phosphorus Total (P) mg/l	0.023	0.019	—
Phosphorus Ortho (P) mg/l	L 0.003	0.004	—
Inorganic Phosphorus (P) mg/l	0.003	0.004	—
Potassium (K) mg/l	1.5	0.8	0.4
Non Filterable Residue, mg/l	L 0.1	—	—
Fixed Residue, mg/l	L 0.1	—	—
Mercury (Hg) µg/l	0.43	0.10	L 0.05
Zinc (Zn) mg/l	0.007	L 0.002	0.00[illegible]
Sodium (Na) mg/l	3.5	2.8	1.1
Silica (SiO_2) mg/l	4.9	5.3	1.5
Sulphate (SO_4) mg/l	5.1	1.3	0.3[illegible]
Calcium (Ca) mg/l	41.3	41.5	13.9
Hardness Total ($CaCO_3$) mg/l	136.	129.	40.9
Alkalinity Total ($CaCO_3$) mg/l	129.	123.	37.2
Specific Conductance, micromho/cm	260.	255.	80.
Total Inorganic Carbon (C) mg/l	25.	22.	8.
Total Organic Carbon (C) mg/l	17.	14.	11.
Total Coliform (M.P.N.)	15.	9.	9.
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 2 Little Beaver River near mouth

CONSTITUENTS	SAMPLING DATES Sept. 26/73	Feb. 22/74	June 13/74
Turbidity	6.3	2.3	2.
Temperature (Field) °C	——	0.0	——
Temperature (Lab) °C	21.2	20.3	25.6
Colour	50.	40.	50.
pH	7.9	7.4	7.7
Chloride (Cl) mg/l	2.5	3.2	1.4
Copper (Cu) mg/l	L0.001	0.005	L0.001
Fluoride (F) mg/l	0.06	0.07	L0.05
Iron (Fe) mg/l	0.05	0.14	L0.040
Lead (Pb) mg/l	L0.005	0.003	L0.004
Manganese (Mn) mg/l	L0.009	L0.02	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.6	1.1	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	——	0.12	0.01
Phosphorus Total (P) mg/l	0.030	0.015	0.013
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.003	L0.003	0.003
Potassium (K) mg/l	0.4	0.9	0.4
Non Filterable Residue, mg/l	——	——	——
Fixed Residue, mg/l	——	——	——
Mercury (Hg) µg/l	L0.05	L0.03	0.16
Zinc (Zn) mg/l	——	0.001	0.002
Sodium (Na) mg/l	2.8	3.6	1.5
Silica (SiO_2) mg/l	3.0	5.3	1.0
Sulphate (SO_4) mg/l	3.2	4.2	3.6
Calcium (Ca) mg/l	26.	47.	19.
Hardness Total ($CaCO_3$) mg/l	85.	160.	62.
Alkalinity Total ($CaCO_3$) mg/l	82.	147.	58.
Specific Conductance, micromho/cm	168.	307.	119.
Total Inorganic Carbon (C) mg/l	15.	28.	13.
Total Organic Carbon (C) mg/l	14.	16.	12.
Total Coliform (M.P.N.)	93.	93.	4.
Fecal Coliform (M.P.N.)	43.	93.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 2 LITTLE BEAVER RIVER NEAR MOUTH

CONSTITUENTS	SAMPLING DATES July 24/74	Aug. 28/74	
Turbidity	1.5	3.5	
Temperature (Field) °C	19.	--	
Temperature (Lab) °C	24.	22.2	
Colour	L5.	60.	
pH	7.6	7.9	
Chloride (Cl) mg/l	1.4	2.0	
Copper (Cu) mg/l	0.008	0.002	
Fluoride (F) mg/l	0.07	L0.05	
Iron (Fe) mg/l	0.29	0.08	
Lead (Pb) mg/l	0.004	L0.004	
Manganese (Mn) mg/l	L0.01	L0.010	
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.6	
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	L0.01	
Phosphorus Total (P) mg/l	0.003	0.006	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	0.003	
Potassium (K) mg/l	1.1	0.1	
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) microgram/l	L0.05	0.36	
Zinc (Zn) mg/l	0.013	--	
Sodium (Na) mg/l	3.	1.8	
Silica (SiO_2) mg/l	1.1	2.8	
Sulphate (SO_4) mg/l	2.	2.6	
Calcium (Ca) mg/l	12.	21.	
Hardness Total ($CaCO_3$) mg/l	48.	71.	
Alkalinity Total ($CaCO_3$) mg/l	47.	66.	
Specific Conductance, micromho/cm	102.	130.	
Total Inorganic Carbon (C) mg/l	11.	11.	
Total Organic Carbon (C) mg/l	8.	14.	
Total Coliform (M.P.N.)	4.	39.	
Fecal Coliform (M.P.N.)	4.	23.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 3 LITTLE CHURCHILL RIVER AT RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES January 15/72	June 19/72	August 14/72
Turbidity	2.2	2.5	1.3
Temperature (Field)°C	32.	50.	60.
Temperature (Lab)°C	24.9	24.	22.8
Colour	30.	40.	30.
pH	7.9	7.8	7.9
Chloride (Cl) mg/l	1.2	0.9	0.9
Copper (Cu) mg/l	L 0.002	L 0.001	—
Fluoride (F) mg/l	0.13	0.06	—
Iron (Fe) mg/l	0.12	L 0.05	—
Lead (Pb) mg/l	L 0.006	L 0.004	—
Manganese (Mn) mg/l	0.011	L 0.010	—
Nitrogen T. Kjeldahl (N) mg/l	0.57	—	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	L 0.01	L 0.01
Phosphorus Total (P) mg/l	0.018	—	—
Phosphorus Ortho (P) mg/l	0.003	0.003	—
Inorganic Phosphorus (P) mg/l	0.003	0.003	—
Potassium (K) mg/l	1.0	0.6	0.4
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.80	—	—
Zinc (Zn) mg/l	0.005	0.005	—
Sodium (Na) mg/l	1.8	1.3	1.1
Silica (SiO_2) mg/l	4.4	2.1	2.8
Sulphate (SO_4) mg/l	1.4	1.5	5.3
Calcium (Ca) mg/l	33.5	27.7	28.6
Hardness Total ($CaCO_3$) mg/l	113.	82.8	88.6
Alkalinity Total ($CaCO_3$) mg/l	110.	77.9	80.4
Specific Conductance, micromho/cm	222.	158.	154.
Total Inorganic Carbon (C) mg/l	22.	14.	—
Total Organic Carbon (C) mg/l	9.	11.	—
Total Coliform (M.P.N.)	4.	—	—
Fecal Coliform (M.P.N.)	0	—	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 3 LITTLE CHURCHILL RIVER AT RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES September 5/72	September 25/72	March 1/73
Turbidity	2.8	2.1	2.3
Temperature (Field) °C	—	—	32.
Temperature (Lab) °C	24.4	22.1	23.2
Colour	80.	60.	25.
pH	7.8	7.8	8.0
Chloride (Cl) mg/l	1.4	0.9	1.3
Copper (Cu) mg/l	0.002	—	0.002
Fluoride (F) mg/l	0.05	—	—
Iron (Fe) mg/l	0.22	—	—
Lead (Pb) mg/l	L 0.004	—	—
Manganese (Mn) mg/l	L 0.008	—	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	—	—	0.49
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.05	0.11
Phosphorus Total (P) mg/l	0.015	—	0.032
Phosphorus Ortho (P) mg/l	0.006	—	L 0.003
Inorganic Phosphorus (P) mg/l	0.007	—	L 0.003
Potassium (K) mg/l	0.4	0.3	1.0
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.04	—	0.29
Zinc (Zn) mg/l	—	—	0.008
Sodium (Na) mg/l	1.4	1.0	1.8
Silica (SiO_2) mg/l	3.3	2.7	4.6
Sulphate (SO_4) mg/l	1.9	2.1	4.6
Calcium (Ca) mg/l	22.2	18.0	36.8
Hardness Total ($CaCO_3$) mg/l	67.8	63.1	123.
Alkalinity Total ($CaCO_3$) mg/l	65.0	57.3	115.
Specific Conductance, micromho/cm	129.	117.	232.
Total Inorganic Carbon (C) mg/l	7.	—	21.
Total Organic Carbon (C) mg/l	18.	—	11.
Total Coliform (M.P.N.)	460.	—	0.
Fecal Coliform (M.P.N.)	9	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 3 LITTLE CHURCHILL RIVER AT RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES July 11/73	October 5/73	October 16/73
Turbidity	1.5	5.2	4.3
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	26.0	21.3	25.1
Colour	5.	30.	40.
pH	8.2	7.9	7.8
Chloride (Cl) mg/l	1.0	1.7	2.1
Copper (Cu) mg/l	0.003	0.002	0.001
Fluoride (F) mg/l	0.06	0.09	0.07
Iron (Fe) mg/l	L 0.05	0.03	L 0.04
Lead (Pb) mg/l	L 0.004	L 0.008	L 0.008
Manganese (Mn) mg/l	L 0.009	L 0.009	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.51	0.3	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.02	0.02
Phosphorus Total (P) mg/l	0.007	0.003	0.011
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.080	L 0.003
Potassium (K) mg/l	0.6	0.7	0.7
Non Filterable Residue, mg/l	—	7.5	—
Fixed Residue, mg/l	—	L 0.1	—
Mercury (Hg) µg/l	0.04	L 0.03	L 0.04
Zinc (Zn) mg/l	L 0.001	0.004	0.002
Sodium (Na) mg/l	1.5	1.6	1.9
Silica (SiO_2) mg/l	2.9	3.4	3.2
Sulphate (SO_4) mg/l	2.7	2.6	3.0
Calcium (Ca) mg/l	30.	35.	29.
Hardness Total ($CaCO_3$) mg/l	97.	109.	96.
Alkalinity Total ($CaCO_3$) mg/l	93.	181.	91.
Specific Conductance, micromho/cm	182.	165.	188.
Total Inorganic Carbon (C) mg/l	16.	19.	20.
Total Organic Carbon (C) mg/l	9.	10.	11.
Total Coliform (M.P.N.)	15.	15.	9
Fecal Coliform (M.P.N.)	0	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 3 LITTLE CHURCHILL RIVER AT RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES February 22/74		
Turbidity	1.0		
Temperature (Field) °C	0.0		
Temperature (Lab) °C	20.9		
Colour	15.		
pH	7.7		
Chloride (Cl) mg/l	1.3		
Copper (Cu) mg/l	0.004		
Fluoride (F) mg/l	0.11		
Iron (Fe) mg/l	0.05		
Lead (Pb) mg/l	0.003		
Manganese (Mn) mg/l	L 0.02		
Nitrogen T. Kjeldahl (N) mg/l	0.7		
Nitrogen Nitrate, Nitrite (N) mg/l	0.30		
Phosphorus Total (P) mg/l	0.009		
Phosphorus Ortho (P) mg/l	L 0.003		
Inorganic Phosphorus (P) mg/l	L 0.003		
Potassium (K) mg/l	0.8		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	L 0.03		
Zinc (Zn) mg/l	L 0.001		
Sodium (Na) mg/l	1.9		
Silica (SiO_2) mg/l	4.9		
Sulphate (SO_4) mg/l	4.0		
Calcium (Ca) mg/l	37.		
Hardness Total ($CaCO_3$) mg/l	131.		
Alkalinity Total ($CaCO_3$) mg/l	120.		
Specific Conductance, micromho/cm	252.		
Total Inorganic Carbon (C) mg/l	26.		
Total Organic Carbon (C) mg/l	10.		
Total Coliform (M.P.N.)			
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 3 LITTLE CHURCHILL RIVER @ RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES March 28/74	August 12/74	
Turbidity	1.9	2.8	
Temperature (Field) °C	--		
Temperature (Lab) °C	18.9	18.2	
Colour	20.	20.	
pH	7.5	8.1	
Chloride (Cl) mg/l	2.7	1.8	
Copper (Cu) mg/l	0.003	0.002	
Fluoride (F) mg/l	0.08	0.07	
Iron (Fe) mg/l	L0.03	0.07	
Lead (Pb) mg/l	0.004	0.005	
Manganese (Mn) mg/l	L0.010	L0.01	
Nitrogen T. Kjeldahl (N) mg/l	1.0	0.7	
Nitrogen Nitrate, Nitrite (N) mg/l	0.13	0.25	
Phosphorus Total (P) mg/l	0.016	0.008	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	0.016	0.003	
Potassium (K) mg/l	1.1	0.4	
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	--		
Mercury (Hg) µg/l	L0.05	0.06	
Zinc (Zn) mg/l	L0.001	0.005	
Sodium (Na) mg/l	2.3	1.4	
Silica (SiO_2) mg/l	5.2	3.9	
Sulphate (SO_4) mg/l	4.7	4.4	
Calcium (Ca) mg/l	39.	28.	
Hardness Total ($CaCO_3$) mg/l	133.	99.	
Alkalinity Total ($CaCO_3$) mg/l	126.	93.	
Specific Conductance, micromho/cm	262.	182.	
Total Inorganic Carbon (C) mg/l	30.	16.	
Total Organic Carbon (C) mg/l	9.	9.	
Total Coliform (M.P.N.)	460.	23.	
Fecal Coliform (M.P.N.)		0.	
Boron Dissolved		0.1	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 3 LITTLE CHURCHILL RIVER AT RECLUSE LAKE

CONSTITUENTS	SAMPLING DATES		
	Oct. 3/74		
Turbidity	2.5		
Temperature (Field)°C	2.0		
Temperature (Lab)°C	18.2		
Colour	20.		
pH	8.0		
Chloride (Cl) mg/l	1.3		
Copper (Cu) mg/l	0.002		
Fluoride (F) mg/l	L0.05		
Iron (Fe) mg/l	0.04		
Lead (Pb) mg/l	0.005		
Manganese (Mn) mg/l	L0.010		
Nitrogen T. Kjeldahl (N) mg/l	0.5		
Nitrogen Nitrate, Nitrite (N) mg/l	0.01		
Phosphorus Total (P) mg/l	0.008		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	0.003		
Potassium (K) mg/l	0.6		
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	--		
Mercury (Hg) ug/l	0.07		
Zinc (Zn) mg/l	0.002		
Sodium (Na) mg/l	1.7		
Silica (SiO_2) mg/l	3.0		
Sulphate (SO_4) mg/l	3.0		
Calcium (Ca) mg/l	28		
Hardness Total ($CaCO_3$) mg/l	98		
Alkalinity Total ($CaCO_3$) mg/l	91		
Specific Conductance, micromho/cm	185		
Total Inorganic Carbon (C) mg/l	20		
Total Organic Carbon (C) mg/l	11		
Total Coliform (M.P.N.)	4		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES June 20/72	August 15/72	September 5/72
Turbidity	1.7	0.7	2.5
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	24.0	22.8	24.8
Colour	10	10	5.
pH	7.5	7.5	7.7
Chloride (Cl) mg/l	1.0	0.8	1.1
Copper (Cu) mg/l	—	—	0.003
Fluoride (F) mg/l	0.03	—	0.07
Iron (Fe) mg/l	—	—	—
Lead (Pb) mg/l	—	—	L 0.005
Manganese (Mn) mg/l	—	—	L 0.005
Nitrogen T. Kjeldahl (N) mg/l	—	—	—
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	L 0.01	0.02
Phosphorus Total (P) mg/l	—	—	0.025
Phosphorus Ortho (P) mg/l	—	—	L 0.003
Inorganic Phosphorus (P) mg/l	—	0.8	L 0.003
Potassium (K) mg/l	1.1	—	0.9
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	1.98
Zinc (Zn) mg/l	—	—	0.005
Sodium (Na) mg/l	2.5	2.0	2.3
Silica (SiO_2) mg/l	1.6	1.2	2.1
Sulphate (SO_4) mg/l	3.7	1.9	3.9
Calcium (Ca) mg/l	13.3	14.0	10.9
Hardness Total ($CaCO_3$) mg/l	41.9	43.3	41.0
Alkalinity Total ($CaCO_3$) mg/l	94.6	42.0	43.5
Specific Conductance, micromho/cm	—	89.6	97.4
Total Inorganic Carbon (C) mg/l	—	—	7.
Total Organic Carbon (C) mg/l	—	—	7.
Total Coliform (M.P.N.)	—	—	150
Fecal Coliform (M.P.N.)	—	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Sample contaminated

STATION # 4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES September 25/72	January 28/73	March 1/73
Turbidity	2.9	2.7	3.0
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	22.	23.	23.4
Colour	5.	10.	20.
pH	7.7	7.6	7.8
Chloride (Cl) mg/l	0.8	1.1	1.2
Copper (Cu) mg/l	0.002	0.002	0.001
Fluoride (F) mg/l	0.07	0.09	0.07
Iron (Fe) mg/l	L 0.04	0.01	0.07
Lead (Pb) mg/l	L 0.010	L 0.002	—
Manganese (Mn) mg/l	L 0.003	L 0.010	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	—	0.45	0.31
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.05	0.08
Phosphorus Total (P) mg/l	—	0.015	0.018
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	0.9	1.4	1.3
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	0.11
Zinc (Zn) mg/l	0.002	0.005	0.036
Sodium (Na) mg/l	2.0	3.	3.0
Silica (SiO_2) mg/l	1.1	2.7	3.0
Sulphate (SO_4) mg/l	1.0	4.5	4.7
Calcium (Ca) mg/l	13.5	13.2	12.7
Hardness Total ($CaCO_3$) mg/l	41.8	44.2	47.1
Alkalinity Total ($CaCO_3$) mg/l	41.8	43.6	45.2
Specific Conductance, micromho/cm	89.1	93.8	99.
Total Inorganic Carbon (C) mg/l	7.	11.	9.
Total Organic Carbon (C) mg/l	6.	8.	9.
Total Coliform (M.P.N.)	—	—	0
Fecal Coliform (M.P.N.)	—	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES March 31/73	June 11/73	July 11/73
Turbidity	2.7	2.3	1.2
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	22.	24.0	26.0
Colour	10.	5.	5.
pH	7.7	7.4	7.8
Chloride (Cl) mg/l	1.8	0.9	0.9
Copper (Cu) mg/l	0.003	0.002	0.002
Fluoride (F) mg/l	0.08	0.09	0.06
Iron (Fe) mg/l	0.01	L 0.03	0.05
Lead (Pb) mg/l	—	L 0.005	0.004
Manganese (Mn) mg/l	L 0.008	0.006	0.009
Nitrogen T. Kjeldahl (N) mg/l	0.42	0.44	0.31
Nitrogen Nitrate, Nitrite (N) mg/l	0.08	0.06	0.01
Phosphorus Total (P) mg/l	0.014	0.005	0.003
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	0.003
Potassium (K) mg/l	1.3	1.0	1.0
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.41	L 0.02	0.04
Zinc (Zn) mg/l	0.002	L 0.002	0.011
Sodium (Na) mg/l	2.8	2.7	2.5
Silica (SiO_2) mg/l	3.6	2.1	1.2
Sulphate (SO_4) mg/l	3.1	3.4	2.0
Calcium (Ca) mg/l	13.6	12.1	10.0
Hardness Total ($CaCO_3$) mg/l	45.4	43.4	39.0
Alkalinity Total ($CaCO_3$) mg/l	45.0	42.4	39.0
Specific Conductance, micromho/cm	101.	97.	83.0
Total Inorganic Carbon (C) mg/l	10.	9.	6.0
Total Organic Carbon (C) mg/l	7.	7.	8.
Total Coliform (M.P.N.)	150	93	0
Fecal Coliform (M.P.N.)	0	93	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES August 13/73	September 17/73	October 16/73
Turbidity	.8	2.8	3.9
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	23.7	22.2	25.0
Colour	10.	10.	20.
pH	7.4	7.5	7.5
Chloride (Cl) mg/l	1.4	0.9	1.5
Copper (Cu) mg/l	0.002	L 0.001	L 0.001
Fluoride (F) mg/l	.08	0.08	0.07
Iron (Fe) mg/l	.08	L 0.02	L 0.04
Lead (Pb) mg/l	L0.005	L 0.005	L 0.009
Manganese (Mn) mg/l	L0.008	L 0.009	L 0.01
Nitrogen T. Kjeldahl (N) mg/l	0.3	0.7	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	—	L 0.01	0.19
Phosphorus Total (P) mg/l	0.006	0.015	0.007
Phosphorus Ortho (P) mg/l	—	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	—	L 0.003	0.006
Potassium (K) mg/l	1.0	0.9	1.1
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.03	L 0.05	L 0.04
Zinc (Zn) mg/l	0.010	0.002	0.002
Sodium (Na) mg/l	2.4	2.2	2.6
Silica (SiO_2) mg/l	2.7	2.2	1.7
Sulphate (SO_4) mg/l	1.8	2.3	1.7
Calcium (Ca) mg/l	10.	11.	11.
Hardness Total ($CaCO_3$) mg/l	36.	39.	36.
Alkalinity Total ($CaCO_3$) mg/l	37.	37.	36.
Specific Conductance, micromho/cm	79.	79.	82.
Total Inorganic Carbon (C) mg/l	—	8.	6.
Total Organic Carbon (C) mg/l	—	7.	6.
Total Coliform (M.P.N.)	0.	—	4.
Fecal Coliform (M.P.N.)	0	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES February 22/71		
Turbidity	1.0		
Temperature (Field) °C	0.0		
Temperature (Lab) °C	21.3		
Colour	10.		
pH	7.3		
Chloride (Cl) mg/l	1.2		
Copper (Cu) mg/l	0.003		
Fluoride (F) mg/l	0.11		
Iron (Fe) mg/l	L 0.04		
Lead (Pb) mg/l	L 0.002		
Manganese (Mn) mg/l	L 0.02		
Nitrogen T. Kjeldahl (N) mg/l	0.9		
Nitrogen Nitrate, Nitrite (N) mg/l	0.20		
Phosphorus Total (P) mg/l	0.01		
Phosphorus Ortho (P) mg/l	L 0.003		
Inorganic Phosphorus (P) mg/l	L 0.003		
Potassium (K) mg/l	1.2		
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	0.03		
Zinc (Zn) mg/l	0.002		
Sodium (Na) mg/l	3.1		
Silica (SiO_2) mg/l	3.0		
Sulphate (SO_4) mg/l	5.0		
Calcium (Ca) mg/l	13.		
Hardness Total ($CaCO_3$) mg/l	43.		
Alkalinity Total ($CaCO_3$) mg/l	42.		
Specific Conductance, micromho/cm	100.		
Total Inorganic Carbon (C) mg/l	9.		
Total Organic Carbon (C) mg/l	9.		
Total Coliform (M.P.N.)	4.		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 4 CHURCHILL RIVER AT FIDLER LAKE

CONSTITUENTS	SAMPLING DATES June 18, 1974	July 24, 1974	
Turbidity	0.5	1.5	
Temperature (Field) °C	11.	19.	
Temperature (Lab) °C	24.7	23.9	
Colour	20.	L5.	
pH	7.8	7.5	
Chloride (Cl) mg/l	1.0	.8	
Copper (Cu) mg/l	0.003	L0.001	
Fluoride (F) mg/l	0.07	0.09	
Iron (Fe) mg/l	0.060	L0.04	
Lead (Pb) mg/l	L0.004	L0.004	
Manganese (Mn) mg/l	L0.010	0.31	
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	0.30	0.02	
Phosphorus Total (P) mg/l	0.010	0.003	
Phosphorus Ortho (P) mg/l	—	L0.003	
Inorganic Phosphorus (P) mg/l	—	L0.003	
Potassium (K) mg/l	1.0	1.1	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) µg/l	—	L0.05	
Zinc (Zn) mg/l	0.088	0.001	
Sodium (Na) mg/l	3.2	3.	
Silica (SiO_2) mg/l	1.7	1.6	
Sulphate (SO_4) mg/l	3.7	1.9	
Calcium (Ca) mg/l	14.	12.	
Hardness Total ($CaCO_3$) mg/l	49.	46.	
Alkalinity Total ($CaCO_3$) mg/l	48.	46.	
Specific Conductance, micromho/cm	106.	100.	
Total Inorganic Carbon (C) mg/l	11.	10.	
Total Organic Carbon (C) mg/l	7.	8.	
Total Coliform (M.P.N.)		0.	
Fecal Coliform (M.P.N.)		0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid Contaminated, Disregard this data

STATION # 5 -GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES June 19, 1972	Aug. 14, 1972	Sept. 5, 1972
Turbidity	2.3	1.3	4.2
Temperature (Field)°C	---	---	---
Temperature (Lab)°C	30.5	22.8	24.5
Colour	30.	20.	40.
pH	7.7	7.8	8.1
Chloride (Cl) mg/l	0.7	0.5	2.2
Copper (Cu) mg/l	L 0.001	0.001	0.001
Fluoride (F) mg/l	L 0.05	0.05	0.06
Iron (Fe) mg/l	L 0.05	0.03	0.16
Lead (Pb) mg/l	L 0.05	L 0.004	L 0.02
Manganese (Mn) mg/l	L 0.05	L 0.010	L 0.01
Nitrogen T. Kjeldahl (N) mg/l	---	---	---
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.02	0.37
Phosphorus Total (P) mg/l	---	---	0.015
Phosphorus Ortho (P) mg/l	L 0.003	0.003	0.02
Inorganic Phosphorus (P) mg/l	0.005	0.004	0.010
Potassium (K) mg/l	0.5	0.4	0.5
Non Filterable Residue, mg/l	---	---	4.5
Fixed Residue, mg/l	---	---	0.5
Mercury (Hg) µg/l	---	---	0.09*
Zinc (Zn) mg/l	0.005	0.002	0.00
Sodium (Na) mg/l	0.9	0.7	2.1
Silica (SiO_2) mg/l	2.1	2.7	2.9
Sulphate (SO_4) mg/l	0.5	0.63	0.96
Calcium (Ca) mg/l	20.5	22.0	22.9
Hardness Total ($CaCO_3$) mg/l	61.9	65.7	69.2
Alkalinity Total ($CaCO_3$) mg/l	58.4	60.9	65.4
Specific Conductance, micromho/cm	124.	121.	129.
Total Inorganic Carbon (C) mg/l	11.	7.	9.
Total Organic Carbon (C) mg/l	10.	10.	14.
Total Coliform (M.P.N.)	---	---	1500+
Fecal Coliform (M.P.N.)	---	---	23.

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Sample Contaminated

STATION # 5 - GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES Sept. 25, 1972	Jan. 27, 1973	Mar. 1, 1973
Turbidity	4.2	1.0	2.0
Temperature (Field) °C	---	32°	32°
Temperature (Lab) °C	22.0	23.	23.4
Colour	20.	25.	25.
pH	8.2	7.9	7.9
Chloride (Cl) mg/l	0.6	0.7	1.0
Copper (Cu) mg/l	0.001	L 0.001	0.002
Fluoride (F) mg/l	L 0.05	0.07	0.07
Iron (Fe) mg/l	L 0.04	0.04	0.02
Lead (Pb) mg/l	L 0.010	L 0.002	L 0.005
Manganese (Mn) mg/l	L 0.003	0.95	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	---	0.41	0.60
Nitrogen Nitrate, Nitrite (N) mg/l	0.60	0.05	0.06
Phosphorus Total (P) mg/l	---	0.011	0.011
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	0.5	0.5	0.8
Non Filterable Residue, mg/l	8.2	---	---
Fixed Residue, mg/l	4.2	---	---
Mercury (Hg) µg/l	---	---	0.11
Zinc (Zn) mg/l	0.002	0.003	0.011
Sodium (Na) mg/l	1.1	1.4	1.5
Silica (SiO_2) mg/l	2.4	3.3	3.0
Sulphate (SO_4) mg/l	0.50	1.0	6.2
Calcium (Ca) mg/l	21.9	27.6	28.3
Hardness Total ($CaCO_3$) mg/l	65.2	90.1	85.9
Alkalinity Total ($CaCO_3$) mg/l	61.3	84.4	84.1
Specific Conductance, micromho/cm	122.	172.	166.
Total Inorganic Carbon (C) mg/l	13.	21.	13.
Total Organic Carbon (C) mg/l	10.	11.	11.
Total Coliform (M.P.N.)	---	---	9.
Fecal Coliform (M.P.N.)	---	---	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 5 - GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES Mar. 31, 1973	June 11, 1973	July 10, 1973
Turbidity	6.8	1.1	10.5
Temperature (Field) °C	32°	---	---
Temperature (Lab) °C	22.0	24.0	24.0
Colour	25.	25.	15.
pH	7.9	7.9	8.0
Chloride (Cl) mg/l	2.7	0.6	0.6
Copper (Cu) mg/l	0.006	0.001	0.005
Fluoride (F) mg/l	0.07	0.07	L 0.05
Iron (Fe) mg/l	0.03	L 0.03	L 0.04
Lead (Pb) mg/l	L 0.004	L 0.005	L 0.002
Manganese (Mn) mg/l	0.012	L 0.006	L 0.004
Nitrogen T. Kjeldahl (N) mg/l	0.91	0.55	0.51
Nitrogen Nitrate, Nitrite (N) mg/l	0.72	L 0.01	0.15
Phosphorus Total (P) mg/l	0.027	0.006	0.011
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	0.8	0.4	0.6
Non Filterable Residue, mg/l	15.6	---	---
Fixed Residue, mg/l	10.0	---	---
Mercury (Hg) µg/l	0.10	0.31	0.10
Zinc (Zn) mg/l	0.012	L 0.002	L 0.003
Sodium (Na) mg/l	1.3	1.5	1.3
Silica (SiO_2) mg/l	3.2	2.0	2.1
Sulphate (SO_4) mg/l	3.4	0.8	5.0
Calcium (Ca) mg/l	30.7	18.6	20.
Hardness Total ($CaCO_3$) mg/l	90.6	63.3	66.
Alkalinity Total ($CaCO_3$) mg/l	83.2	60.5	63.
Specific Conductance, micromho/cm	181.	123.	145.
Total Inorganic Carbon (C) mg/l	18.	13.	11.
Total Organic Carbon (C) mg/l	0.	7.	9.
Total Coliform (M.P.N.)	0.	4.	15.
Fecal Coliform (M.P.N.)	0.	4.	4.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 5 GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES Aug. 13/73	Sept. 17/73	Oct. 16/73
Turbidity	0.7	4.6	12.
Temperature (Field) °C	18.0	--	--
Temperature (Lab) °C	23.5	22.0	24.9
Colour	20.0	30.	40.
pH	7.9	7.6	7.6
Chloride (Cl) mg/l	1.2	.8	1.4
Copper (Cu) mg/l	L0.002	0.001	0.001
Fluoride (F) mg/l	0.06	0.05	0.06
Iron (Fe) mg/l	0.11	L0.04	L0.04
Lead (Pb) mg/l	L0.005	L0.005	L0.008
Manganese (Mn) mg/l	0.008	L0.009	L0.010
Nitrogen T. Kjeldahl (N) mg/l	--	0.6	0.7
Nitrogen Nitrate, Nitrite (N) mg/l		0.11	0.02
Phosphorus Total (P) mg/l	0.005	0.018	0.020
Phosphorus Ortho (P) mg/l	--	L0.003	L0.003
Inorganic Phosphorus (P) mg/l		L0.003	L0.003
Potassium (K) mg/l	0.6	0.6	0.7
Non Filterable Residue, mg/l	--	--	--
Fixed Residue, mg/l		--	--
Mercury (Hg) µg/l	L0.03	L0.05	L0.04
Zinc (Zn) mg/l	0.004	0.002	0.002
Sodium (Na) mg/l	1.3	1.2	1.5
Silica (SiO_2) mg/l	2.5	2.9	2.6
Sulphate (SO_4) mg/l	1.7	2.8	2.2
Calcium (Ca) mg/l	23.	23.	21.
Hardness Total ($CaCO_3$) mg/l	68.	74.	69.
Alkalinity Total ($CaCO_3$) mg/l	64.	68.	65.
Specific Conductance, micromho/cm	125.	133.	131.
Total Inorganic Carbon (C) mg/l	--	14.	13.
Total Organic Carbon (C) mg/l		13.	11.
Total Coliform (M.P.N.)	28.	--	93.
Fecal Coliform (M.P.N.)	0.	--	9.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 5 GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES Feb. 22/74	June 18/74	
Turbidity	1.9	0.5	
Temperature (Field)°C	0.0	13.	
Temperature (Lab)°C	20.0	24.5	
Colour	20.	20.	
pH	7.5	7.8	
Chloride (Cl) mg/l	0.9	0.6	
Copper (Cu) mg/l	0.005	0.002	
Fluoride (F) mg/l	0.06	L0.05	
Iron (Fe) mg/l	L0.04	L0.04	
Lead (Pb) mg/l	0.003	0.004	
Manganese (Mn) mg/l	L0.02	L0.01	
Nitrogen T. Kjeldahl (N) mg/l	[illegible]	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	[illegible]	0.23	
Phosphorus Total (P) mg/l	0.012	0.010	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	
Potassium (K) mg/l	0.9	0.5	
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) ug/l	L0.03	0.15	
Zinc (Zn) mg/l	L0.001	0.002	
Sodium (Na) mg/l	1.6	1.2	
Silica (SiO_2) mg/l	3.0	1.6	
Sulphate (SO_4) mg/l	3.4	2.6	
Calcium (Ca) mg/l	28.	21.	
Hardness Total ($CaCO_3$) mg/l	88.	70.	
Alkalinity Total ($CaCO_3$) mg/l	84.	66.	
Specific Conductance, micromho/cm	179.	131.	
Total Inorganic Carbon (C) mg/l	17.	15.	
Total Organic Carbon (C) mg/l	12.	8.	
Total Coliform (M.P.N.)	9.	0.	
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 5 GAUER RIVER @ THORSTEINSON LAKE

CONSTITUENTS	SAMPLING DATES July 24/74	August 12/74	
Turbidity	2.	2.5	
Temperature (Field) °C	21.	--	
Temperature (Lab) °C	24.	18.7	
Colour	5.	20.	
pH	7.8	7.8	
Chloride (Cl) mg/l	1.	0.8	
Copper (Cu) mg/l	L .001	0.002	
Fluoride (F) mg/l	.06	--	
Iron (Fe) mg/l	L .04	L0.04	
Lead (Pb) mg/l	L .004	L0.004	
Manganese (Mn) mg/l	L .01	L0.01	
Nitrogen T. Kjeldahl (N) mg/l	.6	0.8	
Nitrogen Nitrate, Nitrite (N) mg/l	.04	L0.01	
Phosphorus Total (P) mg/l	.003	0.010	
Phosphorus Ortho (P) mg/l	L .003	L0.003	
Inorganic Phosphorus (P) mg/l	.003	L0.004	
Potassium (K) mg/l	.5	0.5	
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) microgram/l	L .05	L0.05	
Zinc (Zn) mg/l	.002	0.002	
Sodium (Na) mg/l	1.2	1.2	
Silica (SiO_2) mg/l	1.8	2.8	
Sulphate (SO_4) mg/l	1.7	3.1	
Calcium (Ca) mg/l	22.	21.	
Hardness Total ($CaCO_3$) mg/l	71.	70.	
Alkalinity Total ($CaCO_3$) mg/l	67.	70.	
Specific Conductance, micromho/cm	137.	139.	
Total Inorganic Carbon (C) mg/l	15.	11.	
Total Organic Carbon (C) mg/l	10.	9.	
Total Coliform (M.P.N.)	4.	93.	
Fecal Coliform (M.P.N.)	0.	0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES June 19/72	August 14/72	September 5/72
Turbidity	3.0	0.8	2.2
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	23.5	22.8	24.4
Colour	40	20	30
pH	7.5	7.9	7.8
Chloride (Cl) mg/l	1.0	0.7	1.3
Copper (Cu) mg/l	L 0.001	L 0.001	0.003
Fluoride (F) mg/l	L 0.05	L 0.05	0.05
Iron (Fe) mg/l	L 0.05	0.03	0.21
Lead (Pb) mg/l	L 0.004	L 0.004	L 0.006
Manganese (Mn) mg/l	L 0.010	L 0.010	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	—	—	0.57
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	L 0.01	0.02
Phosphorus Total (P) mg/l	—	—	0.014
Phosphorus Ortho (P) mg/l	0.003	L 0.003	0.006
Inorganic Phosphorus (P) mg/l	0.007	0.003	0.006
Potassium (K) mg/l	0.6	0.3	0.4
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	L 0.04
Zinc (Zn) mg/l	0.005	0.003	0.010
Sodium (Na) mg/l	0.9	0.7	1.3
Silica (SiO_2) mg/l	1.6	1.7	2.0
Sulphate (SO_4) mg/l	1.1	5.3	0.16
Calcium (Ca) mg/l	19.1	21.1	17.9
Hardness Total ($CaCO_3$) mg/l	56.8	63.4	61.7
Alkalinity Total ($CaCO_3$) mg/l	52.3	56.9	62.0
Specific Conductance, microcho/cm	11.0	124	132
Total Inorganic Carbon (C) mg/l	10.	10.	8.
Total Organic Carbon (C) mg/l	11.	11.	13.
Total Coliform (M.P.N.)	—	—	23.
Fecal Coliform (M.P.N.)	—	—	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES		
	September 25/72	December 5/72	January 29/73
Turbidity	4.8	6.5	1.7
Temperature (Field)°C	—	32	32.
Temperature (Lab)°C	22.0	21.3	23.
Colour	30.	20.	30.
pH	8.1	—	7.8
Chloride (Cl) mg/l	0.8	1.2	1.3
Copper (Cu) mg/l	0.001	0.003	0.002
Fluoride (F) mg/l	L 0.05	0.06	0.0[illegible]
Iron (Fe) mg/l	L 0.04	0.03	0.11
Lead (Pb) mg/l	L 0.010	L 0.006	L 0.0[illegible]
Manganese (Mn) mg/l	L 0.003	L 0.005	0.0[illegible]
Nitrogen T. Kjeldahl (N) mg/l	—	0.66	0.[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.66	—	0.0[illegible]
Phosphorus Total (P) mg/l	—	0.018	0.0[illegible]
Phosphorus Ortho (P) mg/l	L 0.003	0.008	L 0.0[illegible]
Inorganic Phosphorus (P) mg/l	L 0.003	0.011	0.003
Potassium (K) mg/l	0.4	1.2	0.9
Non Filterable Residue, mg/l	6.8	16.4	—
Fixed Residue, mg/l	3.8	16.0	—
Mercury (Hg) µg/l	—	0.19	—
Zinc (Zn) mg/l	0.006	0.004	0.00[illegible]
Sodium (Na) mg/l	1.0	2.7	1.3
Silica (SiO_2) mg/l	2.5	1.6	4.4
Sulphate (SO_4) mg/l	0.83	4.0	2.6
Calcium (Ca) mg/l	20.6	13.4	30.3
Hardness Total ($CaCO_3$) mg/l	62.2	51.0	98.2
Alkalinity Total ($CaCO_3$) mg/l	57.6	—	92.6
Specific Conductance, micromho/cm	125.	114.	189.
Total Inorganic Carbon (C) mg/l	12.	10.	25.
Total Organic Carbon (C) mg/l	9.	9.	9.
Total Coliform (M.P.N.)	—	4.	—
Fecal Coliform (M.P.N.)	—	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES March 1/73	March 31/73	June 11/73
Turbidity	5.6	3.4	0.8
Temperature (Field) °C	32.	—	—
Temperature (Lab) °C	23.4	22.4	24.0
Colour	15.	25.	15.
pH	7.7	8.1	7.5
Chloride (Cl) mg/l	1.0	1.6	0.8
Copper (Cu) mg/l	L 0.001	L 0.003	0.002
Fluoride (F) mg/l	0.08	0.08	0.06
Iron (Fe) mg/l	0.04	0.08	L 0.03
Lead (Pb) mg/l	L 0.005	—	L 0.005
Manganese (Mn) mg/l	L 0.008	0.028	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	0.49	0.57	0.34
Nitrogen Nitrate, Nitrite (N) mg/l	0.16	0.31	—
Phosphorus Total (P) mg/l	0.007	0.013	0.007
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	0.8	1.0	0.6
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.15	0.90	0.02
Zinc (Zn) mg/l	0.010	0.008	L 0.003
Sodium (Na) mg/l	1.5	1.5	1.1
Silica (SiO_2) mg/l	3.0	6.0	1.6
Sulphate (SO_4) mg/l	4.2	3.2	1.1
Calcium (Ca) mg/l	13.4	43.0	13.3
Hardness Total ($CaCO_3$) mg/l	50.2	132.	50.2
Alkalinity Total ($CaCO_3$) mg/l	48.9	124.	46.6
Specific Conductance, micromho/cm	104.	259.	100.
Total Inorganic Carbon (C) mg/l	11.	20.	9.
Total Organic Carbon (C) mg/l	8.	6.	9.
Total Coliform (M.P.N.)	0	4	—
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES July 10/73	August 13/73	September 17/73
Turbidity	18.5	0.6	1.9
Temperature (Field)°C	--	--	--
Temperature (Lab)°C	24.0	23.5	22.2
Colour	5.	20.	15.
pH	7.8	7.6	7.6
Chloride (Cl) mg/l	0.8	1.5	1.3
Copper (Cu) mg/l	0.004	L0.002	L0.001
Fluoride (F) mg/l	0.08	0.07	0.07
Iron (Fe) mg/l	L0.04	0.08	L0.02
Lead (Pb) mg/l	0.002	L0.005	L0.005
Manganese (Mn) mg/l	L0.011	0.008	L0.009
Nitrogen T. Kjeldahl (N) mg/l	0.45	0.3	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.09	--	0.01
Phosphorus Total (P) mg/l	0.008	0.006	0.011
Phosphorus Ortho (P) mg/l	L0.003	--	L0.003
Inorganic Phosphorus (P) mg/l	L0.003	--	L0.003
Potassium (K) mg/l	1.0	0.6	0.6
Non Filterable Residue, mg/l	--	--	--
Fixed Residue, mg/l	--	--	--
Mercury (Hg) ug/l	0.06	L0.03	0.06
Zinc (Zn) mg/l	L0.003	0.007	0.002
Sodium (Na) mg/l	2.3	1.7	1.6
Silica (SiO_2) mg/l	1.5	2.0	2.7
Sulphate (SO_4) mg/l	6.0	1.8	0.4
Calcium (Ca) mg/l	12.	17.	18.
Hardness Total ($CaCO_3$) mg/l	43.	52.	57.
Alkalinity Total ($CaCO_3$) mg/l	43.	50.	53.
Specific Conductance, micromho/cm	134.	101.	107.
Total Inorganic Carbon (C) mg/l	7.	--	11.
Total Organic Carbon (C) mg/l	8.	--	10.
Total Coliform (M.P.N.)	0	4.	--
Fecal Coliform (M.P.N.)	0	0	--

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES Oct. 16/73	Feb. 22/74	
Turbidity	3.4	2.9	
Temperature (Field) °C	—	—	
Temperature (Lab) °C	24.9	21.6	
Colour	30.	25.	
pH	7.6	7.2	
Chloride (Cl) mg/l	1.8	3.6	
Copper (Cu) mg/l	0.001	0.004	
Fluoride (F) mg/l	0.06	0.09	
Iron (Fe) mg/l	L 0.04	0.06	
Lead (Pb) mg/l	L 0.008	0.003	
Manganese (Mn) mg/l	L 0.008	L 0.02	
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.9	
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.11	
Phosphorus Total (P) mg/l	0.011	0.01	
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	
Potassium (K) mg/l	0.7	0.9	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) µg/l	L 0.04	L 0.03	
Zinc (Zn) mg/l	0.001	0.001	
Sodium (Na) mg/l	1.6	1.7	
Silica (SiO_2) mg/l	2.4	5.2	
Sulphate (SO_4) mg/l	2.3	4.5	
Calcium (Ca) mg/l	20	34	
Hardness Total ($CaCO_3$) mg/l	66	125	
Alkalinity Total ($CaCO_3$) mg/l	61	110	
Specific Conductance, micromho/cm	125	282	
Total Inorganic Carbon (C) mg/l	9	24	
Total Organic Carbon (C) mg/l	9	11	
Total Coliform (M.P.N.)	4	4	
Fecal Coliform (M.P.N.)	0	0	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES June 18/74	August 12/74	
Turbidity	0.5	1	
Temperature (Field) °C	12.0		
Temperature (Lab) °C	24.6	18.8	
Colour	30.	20.	
pH	7.7	7.8	
Chloride (Cl) mg/l	1.0	1.1	
Copper (Cu) mg/l	.003	0.002	
Fluoride (F) mg/l	.05	0.09	
Iron (Fe) mg/l	L .04	L0.04	
Lead (Pb) mg/l	.005	L0.004	
Manganese (Mn) mg/l	.010	L0.01	
Nitrogen T. Kjeldahl (N) mg/l	.6	0.7	
Nitrogen Nitrate, Nitrite (N) mg/l	.08	L0.01	
Phosphorus Total (P) mg/l	.01	0.005	
Phosphorus Ortho (P) mg/l	L .003	L0.003	
Inorganic Phosphorus (P) mg/l	L .003	L0.003	
Potassium (K) mg/l	.7	0.4	
Non Filterable Residue, mg/l			
Fixed Residue, mg/l			
Mercury (Hg) microgram/l	L .05	0.05	
Zinc (Zn) mg/l	.003	0.002	
Sodium (Na) mg/l	1.6	1.2	
Silica (SiO_2) mg/l	1.8	2.6	
Sulphate (SO_4) mg/l	3.2	4.5	
Calcium (Ca) mg/l	16.0	21.	
Hardness Total ($CaCO_3$) mg/l	59.0	68	
Alkalinity Total ($CaCO_3$) mg/l	55	66	
Specific Conductance, micromho/cm	111.0	134	
Total Inorganic Carbon (C) mg/l	12.0	9	
Total Organic Carbon (C) mg/l	9.0	10	
Total Coliform (M.P.N.)	0.	0	
Fecal Coliform (M.P.N.)	0	0	
Boron Dissolved		0.07	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 6 OLDMAN RIVER @ NORTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES July 24/74	Sept. 21/74	
Turbidity	1.	1.6	
Temperature (Field)°C	21.	7.7	
Temperature (Lab)°C	23.9	23.8	
Colour	10.	20	
pH	7.6	7.8	
Chloride (Cl) mg/l	1.0	1.4	
Copper (Cu) mg/l	L .001	0.001	
Fluoride (F) mg/l	.07	L0.05	
Iron (Fe) mg/l	L .04	0.13	
Lead (Pb) mg/l	L .004	0.008	
Manganese (Mn) mg/l	L .01	0.02	
Nitrogen T. Kjeldahl (N) mg/l	.6	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	.04	L0.01	
Phosphorus Total (P) mg/l	.003	0.01	
Phosphorus Ortho (P) mg/l	L .003	L0.003	
Inorganic Phosphorus (P) mg/l	.003	0.003	
Potassium (K) mg/l	.6	0.5	
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) microgram/l	.12	--	
Zinc (Zn) mg/l	.002	0.21	
Sodium (Na) mg/l	1.7	1.4	
Silica (SiO_2) mg/l	1.8	2.1	
Sulphate (SO_4) mg/l	2.0	2.9	
Calcium (Ca) mg/l	17.	20.	
Hardness Total ($CaCO_3$) mg/l	63.	76.	
Alkalinity Total ($CaCO_3$) mg/l	60.	87.	
Specific Conductance, micromho/cm	125.	128.	
Total Inorganic Carbon (C) mg/l	13.	15.	
Total Organic Carbon (C) mg/l	10.	8.	
Total Coliform (M.P.N.)	0		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 7 SOUTHERN INDIAN LAKE @ MISSI FALLS

CONSTITUENTS	SAMPLING DATES July 10/72	August 8/72	September 2/72
Turbidity	1.3	2.5	3.6
Temperature (Field)°C	15	—	—
Temperature (Lab)°C	23.8	25.1	24.3
Colour	20.	20.0	10
pH	7.8	7.7	7.8
Chloride (Cl) mg/l	1.2	0.8	1.1
Copper (Cu) mg/l	0.002	L 0.001	0.001
Fluoride (F) mg/l	0.07	0.07	0.08
Iron (Fe) mg/l	0.01	L 0.05	0.12
Lead (Pb) mg/l	L 0.004	L 0.006	L 0.004
Manganese (Mn) mg/l	L 0.010	L 0.005	L 0.00
Nitrogen T. Kjeldahl (N) mg/l	0.51	0.38	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	L 0.01	0.0
Phosphorus Total (P) mg/l	0.011	0.015	0.0
Phosphorus Ortho (P) mg/l	L 0.003	0.010	L 0.00
Inorganic Phosphorus (P) mg/l	L 0.003	0.010	L 0.00
Potassium (K) mg/l	1.0	0.9	1.0
Non Filterable Residue, mg/l	—	—	4.8
Fixed Residue, mg/l	—	—	1.0
Mercury (Hg) µg/l	L 0.04	L 0.06	1.59*
Zinc (Zn) mg/l	L 0.001	0.004	0.004
Sodium (Na) mg/l	2.8	2.2	2.5
Silica (SiO_2) mg/l	0.8	2.3	1.0
Sulphate (SO_4) mg/l	4.0	3.3	4.02
Calcium (Ca) mg/l	9.1	9.7	9.2
Hardness Total ($CaCO_3$) mg/l	39.3	40.3	35.
Alkalinity Total ($CaCO_3$) mg/l	37.7	39.5	33.9
Specific Conductance, micromho/cm	85.0	81.0	78.9
Total Inorganic Carbon (C) mg/l	5.0	5.0	4.
Total Organic Carbon (C) mg/l	8.0	9.0	9.
Total Coliform (M.P.N.)	0.	0.	4.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Sample contaminated

STATION # 7 SOUTHERN INDIAN LAKE @ MISSI FALLS

CONSTITUENTS	SAMPLING DATES March 1/73	March 28/73	July 11/73
Turbidity	3.6	3.0	1.5
Temperature (Field) °C	32.	—	—
Temperature (Lab) °C	23.8	23.8	24.7
Colour	20.	15.	5.
pH	7.8	7.2	7.8
Chloride (Cl) mg/l	1.4	1.9	0.8
Copper (Cu) mg/l	0.008	0.004	0.002
Fluoride (F) mg/l	0.09	0.08	0.06
Iron (Fe) mg/l	0.04	0.02	0.03
Lead (Pb) mg/l	L 0.005	L 0.004	0.004
Manganese (Mn) mg/l	L 0.008	L 0.008	0.008
Nitrogen T. Kjeldahl (N) mg/l	0.52	0.80	0.59
Nitrogen Nitrate, Nitrite (N) mg/l	0.058	0.03	0.01
Phosphorus Total (P) mg/l	0.007	0.017	0.028
Phosphorus Ortho (P) mg/l	L 0.003	0.004	0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.004	0.003
Potassium (K) mg/l	1.3	1.6	1.1
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.14	L 0.05	0.13
Zinc (Zn) mg/l	0.015	0.015	0.001
Sodium (Na) mg/l	3.4	3.4	2.6
Silica (SiO_2) mg/l	3.5	3.8	1.3
Sulphate (SO_4) mg/l	5.1	10.0	7.0
Calcium (Ca) mg/l	13.4	13.6	9.5
Hardness Total ($CaCO_3$) mg/l	44.4	46.1	38.0
Alkalinity Total ($CaCO_3$) mg/l	44.5	38.4	35.0
Specific Conductance, micromho/cm	107	105	77
Total Inorganic Carbon (C) mg/l	9	8	6
Total Organic Carbon (C) mg/l	8	9	9
Total Coliform (M.P.N.)	240	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 7 SOUTHERN INDIAN LAKE @ MISSI FALLS

CONSTITUENTS	SAMPLING DATES October 16/73		
Turbidity	3.5		
Temperature (Field) °C	—		
Temperature (Lab) °C	24.1		
Colour	10.		
pH	7.5		
Chloride (Cl) mg/l	1.4		
Copper (Cu) mg/l	0.001		
Fluoride (F) mg/l	0.07		
Iron (Fe) mg/l	0.16		
Lead (Pb) mg/l	0.008		
Manganese (Mn) mg/l	L 0.010		
Nitrogen T. Kjeldahl (N) mg/l	0.7		
Nitrogen Nitrate, Nitrite (N) mg/l	0.03		
Phosphorus Total (P) mg/l	0.009		
Phosphorus Ortho (P) mg/l	L 0.003		
Inorganic Phosphorus (P) mg/l	L 0.003		
Potassium (K) mg/l	1.0		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	L 0.04		
Zinc (Zn) mg/l	0.02		
Sodium (Na) mg/l	2.6		
Silica (SiO_2) mg/l	1.6		
Sulphate (SO_4) mg/l	1.3		
Calcium (Ca) mg/l	9.8		
Hardness Total ($CaCO_3$) mg/l	36.		
Alkalinity Total ($CaCO_3$) mg/l	35.		
Specific Conductance, micromho/cm	77.		
Total Inorganic Carbon (C) mg/l	7.		
Total Organic Carbon (C) mg/l	7.		
Total Coliform (M.P.N.)	75.		
Fecal Coliform (M.P.N.)	7		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 7 CHURCHILL RIVER @ MESSI FALLS

CONSTITUENTS	SAMPLING DATES July 23/74		
Turbidity	.5		
Temperature (Field) °C	19.		
Temperature (Lab) °C	23.9		
Colour	L5.		
pH	7.5		
Chloride (Cl) mg/l	1.4		
Copper (Cu) mg/l	L .001		
Fluoride (F) mg/l	.09		
Iron (Fe) mg/l	L .04		
Lead (Pb) mg/l	L .004		
Manganese (Mn) mg/l	L .01		
Nitrogen T. Kjeldahl (N) mg/l	.5		
Nitrogen Nitrate, Nitrite (N) mg/l	.02		
Phosphorus Total (P) mg/l	.004		
Phosphorus Ortho (P) mg/l	L .003		
Inorganic Phosphorus (P) mg/l	.003		
Potassium (K) mg/l	1.1		
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	--		
Mercury (Hg) microgram/l	L .05		
Zinc (Zn) mg/l	.002		
Sodium (Na) mg/l	3.2		
Silica (SiO_2) mg/l	1.5		
Sulphate (SO_4) mg/l	2.2		
Calcium (Ca) mg/l	12.		
Hardness Total ($CaCO_3$) mg/l	44.		
Alkalinity Total ($CaCO_3$) mg/l	45.		
Specific Conductance, micromho/cm	98.		
Total Inorganic Carbon (C) mg/l	10.		
Total Organic Carbon (C) mg/l	8.		
Total Coliform (M.P.N.)	0		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 8 BARRINGTON RIVER @ SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES June 23/72	August 18/72	September 5/72
Turbidity	3.0	3.0	5.5
Temperature (Field) °C	17.2	19.4	—
Temperature (Lab) °C	24.0	22.8	24.3
Colour	30.	20.	10.
pH	7.2	7.5	7.6
Chloride (Cl) mg/l	0.7	0.5	1.5
Copper (Cu) mg/l	L 0.001	0.003	0.002
Fluoride (F) mg/l	0.06	0.05	0.06
Iron (Fe) mg/l	L 0.05	0.15	L 0.08
Lead (Pb) mg/l	L 0.004	L 0.04	L 0.004
Manganese (Mn) mg/l	L 0.010	L 0.010	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	—	—	—
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.016	0.21
Phosphorus Total (P) mg/l	—	—	0.018
Phosphorus Ortho (P) mg/l	0.003	0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.007	0.004	L 0.003
Potassium (K) mg/l	0.7	0.6	0.8
Non Filterable Residue, mg/l	—	—	L 0.1
Fixed Residue, mg/l	—	—	L 0.1
Mercury (Hg) µg/l	—	0.10*	1.33*
Zinc (Zn) mg/l	L 0.005	0.003	0.002
Sodium (Na) mg/l	1.0	0.9	1.8
Silica (SiO_2) mg/l	1.0	1.4	1.4
Sulphate (SO_4) mg/l	0.8	3.2	2.3
Calcium (Ca) mg/l	6.7	8.2	6.8
Hardness Total ($CaCO_3$) mg/l	21.1	24.4	25.6
Alkalinity Total ($CaCO_3$) mg/l	18.8	20.7	23.8
Specific Conductance, micromho/cm	49.8	48.7	53.0
Total Inorganic Carbon (C) mg/l	4.	—	3.
Total Organic Carbon (C) mg/l	8.	—	9.
Total Coliform (M.P.N.)	—	—	23.
Fecal Coliform (M.P.N.)	—	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Sample contaminated

STATION# 8 BARRINGTON RIVER @ SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES Sept. 25/72	Jan. 22/73	Feb. 27/73
Turbidity	3.6	2.4	2.0
Temperature (Field)°C	--	0	0
Temperature (Lab)°C	22.	25.1	22.2
Colour	10	20	30
pH	7.8	7.2	7.3
Chloride (Cl) mg/l	0.5	0.8	0.7
Copper (Cu) mg/l	0.004	0.003	0.002
Fluoride (F) mg/l	L0.05	0.05	0.07
Iron (Fe) mg/l	L0.04	0.04	0.07
Lead (Pb) mg/l	L0.010	L0.004	--
Manganese (Mn) mg/l	L0.003	0.008	0.011
Nitrogen T. Kjeldahl (N) mg/l	0.60	0.90	0.48
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.03	0.04
Phosphorus Total (P) mg/l	0.013	0.014	0.013
Phosphorus Ortho (P) mg/l	0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.005	0.003	.004
Potassium (K) mg/l	0.5	0.8	1.0
Non Filterable Residue, mg/l	2.6	--	--
Fixed Residue, mg/l	0.3	--	--
Mercury (Hg) µg/l	L0.05	--	0.09
Zinc (Zn) mg/l	0.023	0.011	0.005
Sodium (Na) mg/l	1.1	1.5	1.4
Silica (SiO_2) mg/l	1.4	1.7	1.8
Sulphate (SO_4) mg/l	0.66	3.8	4.1
Calcium (Ca) mg/l	8.1	7.5	8.5
Hardness Total ($CaCO_3$) mg/l	25.4	26.3	29.2
Alkalinity Total ($CaCO_3$) mg/l	22.3	24.2	24.8
Specific Conductance, micromho/cm	52.5	59.3	59.
Total Inorganic Carbon (C) mg/l	5.	6.	7.
Total Organic Carbon (C) mg/l	6.	8.	9.
Total Coliform (M.P.N.)	--	--	1
Fecal Coliform (M.P.N.)	--	--	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 8 BARRINGTON RIVER @ SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES June 11/73	July 11/73	September 10/73
Turbidity	3.0	6.5	5.3
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	24.0	24.7	21.4
Colour	20.	30.	30.
pH	7.2	7.3	7.5
Chloride (Cl) mg/l	0.6	0.6	1.1
Copper (Cu) mg/l	0.002	L 0.002	L 0.001
Fluoride (F) mg/l	0.07	L 0.05	0.06
Iron (Fe) mg/l	0.07	L 0.05	0.03
Lead (Pb) mg/l	L 0.005	L 0.004	L 0.005
Manganese (Mn) mg/l	L 0.006	L 0.008	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	0.39	0.46	—
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.40	0.23
Phosphorus Total (P) mg/l	0.01	0.006	0.01
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	0.004
Potassium (K) mg/l	0.7	0.9	0.8
Non Filterable Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	—
Zinc (Zn) mg/l	L .02	L 0.04	0.09
Sodium (Na) mg/l	L 0.002	L 0.001	0.002
Silica (SiO_2) mg/l	1.2	1.5	1.6
Silica (SO_4) mg/l	1.4	1.7	2.2
Sulphate (SO_4) mg/l	2.1	6.0	2.0
Calcium (Ca) mg/l	6.83	7.8	10.
Hardness Total ($CaCO_3$) mg/l	23.8	29.	30.
Alkalinity Total ($CaCO_3$) mg/l	19.9	25.	28.
Specific Conductance, micromho/cm	52.	60.	61.
Total Inorganic Carbon (C) mg/l	4.	3.	6.
Total Organic Carbon (C) mg/l	10.	10.	7.
Total Coliform (M.P.N.)	3.	4.	4.
Fecal Coliform (M.P.N.)	3.	0.	4.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 8 Barrington River at Southern Indian Lake

CONSTITUENTS	SAMPLING DATES Sept. 20/73	Oct. 15/73	Dec. 17/73
Turbidity	3.4	4.5	3.5
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	22.2	17.5	22.2
Colour	20.	30.	25.
pH	7.2	7.4	6.9
Chloride (Cl) mg/l	0.6	1.2	0.9
Copper (Cu) mg/l	L0.001	L 0.001	0.004
Fluoride (F) mg/l	0.06	L 0.05	0.07
Iron (Fe) mg/l	L 0.04	L 0.04	0.04
Lead (Pb) mg/l	L0.003	L 0.006	L 0.004
Manganese (Mn) mg/l	L 0.009	L 0.008	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	0.2	0.3	0.3
Nitrogen Nitrate, Nitrite (N) mg/l	0.09	0.04	0.21
Phosphorus Total (P) mg/l	0.011	0.012	0.012
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	0.6	0.7	0.7
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	L 0.05	L 0.04	-
Zinc (Zn) mg/l	0.002	0.004	0.010
Sodium (Na) mg/l	1.1	1.4	1.3
Silica (SiO_2) mg/l	1.4	1.6	2.0
Sulphate (SO_4) mg/l	2.5	1.6	3.2
Calcium (Ca) mg/l	7.7	7.6	8.8
Hardness Total ($CaCO_3$) mg/l	24.	26.	27.
Alkalinity Total ($CaCO_3$) mg/l	22.	24.	26.
Specific Conductance, micromho/cm	50.	53.	60.
Total Inorganic Carbon (C) mg/l	5.	6.	6.
Total Organic Carbon (C) mg/l	8.	9.	9.
Total Coliform (M.P.N.)	-	9.	
Fecal Coliform (M.P.N.)	-	0	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 8 BARRINGTON RIVER AT SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES Feb. 18/74	April 8/74	June 26/74
Turbidity	1.8	8.4	5.
Temperature (Field) °C	0.0	0.0	
Temperature (Lab) °C	17.7	14.3	21.3
Colour	20.	35.	40.
pH	7.3	7.5	7.3
Chloride (Cl) mg/l	1.1	1.3	i.s.
Copper (Cu) mg/l	0.001		0.003
Fluoride (F) mg/l	0.08	0.05	i.s.
Iron (Fe) mg/l	L0.04		0.10
Lead (Pb) mg/l	L0.003		L0.004
Manganese (Mn) mg/l	L0.02		0.060
Nitrogen T. Kjeldahl (N) mg/l	0.6	0.6	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.24	0.45
Phosphorus Total (P) mg/l	0.008	0.004	0.023
Phosphorus Ortho (P) mg/l	L0.003		L0.003
Inorganic Phosphorus (P) mg/l	L0.003		0.005
Potassium (K) mg/l	0.8	1.1	i.s.
Non Filterable Residue, mg/l	--	i.s.	i.s.
Fixed Residue, mg/l	--	i.s.	i.s.
Mercury (Hg) µg/l	0.02		0.20
Zinc (Zn) mg/l	L0.002		0.006
Sodium (Na) mg/l	1.6	3.2	i.s.
Silica (SiO_2) mg/l	2.2	4.2	i.s.
Sulphate (SO_4) mg/l	2.6	3.2	3.2
Calcium (Ca) mg/l	8.8	15.	
Hardness Total ($CaCO_3$) mg/l	29.	58.	26.
Alkalinity Total ($CaCO_3$) mg/l	26.	54.	20.
Specific Conductance, micromho/cm	61.	114.	62.
Total Inorganic Carbon (C) mg/l	5.	6.	5.
Total Organic Carbon (C) mg/l	8.	8.	9.
Total Coliform (M.P.N.)	0.	L240.	23.
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s. = insufficient sample

STATION# 8 BARRINGTON RIVER @ SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES July 23/74	August 15/74	Sept. 16/74
Turbidity	2.5	4.5	0.8
Temperature (Field) °C	21.11		
Temperature (Lab) °C	21.8	18.5	21.3
Colour	20.	20.	L5.
pH	7.3	7.5	7.2
Chloride (Cl) mg/l	.8	0.7	0.8
Copper (Cu) mg/l	.001	0.001	0.001
Fluoride (F) mg/l	.05	0.09	0.05
Iron (Fe) mg/l	L .04	L0.04	0.20
Lead (Pb) mg/l	L .004	L0.004	0.001
Manganese (Mn) mg/l	L .01	L0.01	0.010
Nitrogen T. Kjeldahl (N) mg/l	.5	0.5	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	.11	L0.01	L0.01
Phosphorus Total (P) mg/l	.009	0.007	0.007
Phosphorus Ortho (P) mg/l	L .003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	L .003	L0.003	L0.003
Potassium (K) mg/l	.8	0.5	0.7
Non Filterable Residue, mg/l	--	--	--
Fixed Residue, mg/l	--	--	--
Mercury (Hg) microgram/l	.05	L0.05	--
Zinc (Zn) mg/l	.003	0.004	0.001
Sodium (Na) mg/l	1.3	1.0	1.3
Silica (SiO_2) mg/l	1.8	1.6	1.0
Sulphate (SO_4) mg/l	2.3	3.5	3.1
Calcium (Ca) mg/l	8.1	7.2	7.4
Hardness Total ($CaCO_3$) mg/l	32.	24.	24.
Alkalinity Total ($CaCO_3$) mg/l	27.	23.	22.
Specific Conductance, micromho/cm	63.	52.	46.
Total Inorganic Carbon (C) mg/l	6.	5.	4.
Total Organic Carbon (C) mg/l	12.	7.	8.
Total Coliform (M.P.N.)	0.	23.	
Fecal Coliform (M.P.N.)	0	4	
Boron Dissolved		0.07	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES July 6/72	August 9/72	September [illegible]/72
Turbidity	1.5	17.	27.
Temperature (Field) °C	17.2	—	—
Temperature (Lab) °C	23.0	23.2	25.5
Colour	40.	40.	20.
pH	8.1	8.0	8.0
Chloride (Cl) mg/l	13.4	14.2	16.0
Copper (Cu) mg/l	0.002	0.002	0.00[illegible]
Fluoride (F) mg/l	0.07	0.07	0.09
Iron (Fe) mg/l	0.01	0.11	L 0.0[illegible]
Lead (Pb) mg/l	L 0.004	0.003	L 0.0[illegible]
Manganese (Mn) mg/l	L 0.010	L 0.005	L 0.0[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.44	0.48	0.4[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.01	0.1[illegible]	0.0[illegible]
Phosphorus Total (P) mg/l	0.028	0.032	0.0[illegible]
Phosphorus Ortho (P) mg/l	0.010	0.010	0.0[illegible]
Inorganic Phosphorus (P) mg/l	0.011	0.010	0.0[illegible]
Potassium (K) mg/l	1.9	1.7	2.2
Non Filterable Residue, mg/l	5.2	5.2	32.0
Fixed Residue, mg/l	1.2	44.	27.0
Mercury (Hg) µg/l	0.25	0.11	0.91
Zinc (Zn) mg/l	L 0.01	0.018	
Sodium (Na) mg/l	11.9	12.4	13.8
Silica (SiO_2) mg/l	1.0	1.8	1.8
Sulphate (SO_4) mg/l	22.6	20.4	23.[illegible]
Calcium (Ca) mg/l	29.1	27.5	28.[illegible]
Hardness Total ($CaCO_3$) mg/l	105.	99.	111.
Alkalinity Total ($CaCO_3$) mg/l	88.	82.6	92.[illegible]
Specific Conductance, micromho/cm	255.	256.	289.
Total Inorganic Carbon (C) mg/l	14.	9.	11.
Total Organic Carbon (C) mg/l	15.	9.	12.
Total Coliform (M.P.N.)	43.	4.	75.
Fecal Coliform (M.P.N.)	—	0	0

IMCHED MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES October 5/72	November 3/72	December
Turbidity	9.5	16.	14.
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	23.0	21.2	22.0
Colour	20.	20.	30.
pH	8.2	7.9	8.1
Chloride (Cl) mg/l	15.0	17.2	15.5
Copper (Cu) mg/l	L 0.002	0.015	0.0
Fluoride (F) mg/l	0.08	0.07	0.0
Iron (Fe) mg/l	L 0.04	L 0.04	L 0.0
Lead (Pb) mg/l	L 0.008	0.014	0.0
Manganese (Mn) mg/l	L 0.008	L 0.010	L 0.
Nitrogen T. Kjeldahl (N) mg/l	0.68	2.26	0.
Nitrogen Nitrate, Nitrite (N) mg/l	0.52	0.38	0.
Phosphorus Total (P) mg/l	0.033	0.040	0.
Phosphorus Ortho (P) mg/l	0.006	L 0.003	0.
Inorganic Phosphorus (P) mg/l	0.006	L 0.003	0.
Potassium (K) mg/l	2.2	3.3	2.
Non Filterable Residue, mg/l	—	17.2	—
Fixed Residue, mg/l	—	12.4	—
Mercury (Hg) µg/l	0.62	0.26	0.
Zinc (Zn) mg/l	L 0.001	0.031	0.
Sodium (Na) mg/l	14.7	15.7	15.7
Silica (SiO_2) mg/l	1.3	1.1	1.0
Sulphate (SO_4) mg/l	22.8	26.0	28.3
Calcium (Ca) mg/l	31.3	38.3	36.4
Hardness Total ($CaCO_3$) mg/l	119.	124.	134.
Alkalinity Total ($CaCO_3$) mg/l	97.9	107.	115.
Specific Conductance, micromho/cm	289.	329.	332.
Total Inorganic Carbon (C) mg/l	13.	20.	23.
Total Organic Carbon (C) mg/l	6.	15.	10.
Total Coliform (M.P.N.)	9.	0	9
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES January 3/73	February 7/73	March 1/73
Turbidity	12	7.6	6.4
Temperature (Field)°C	—	0	0
Temperature (Lab)°C	25.	25.	23.2
Colour	20	20	15
pH	8.0	8.2	8.3
Chloride (Cl) mg/l	15.8	17.0	17.0
Copper (Cu) mg/l	0.002	L 0.002	0.002
Fluoride (F) mg/l	0.09	0.07	0.10
Iron (Fe) mg/l	L 0.01	0.01	0.03
Lead (Pb) mg/l	L 0.008	L 0.003	—
Manganese (Mn) mg/l	0.013	0.006	0.011
Nitrogen T. Kjeldahl (N) mg/l	0.44	0.71	0.64
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.19	0.23
Phosphorus Total (P) mg/l	—	—	L 0.00
Phosphorus Ortho (P) mg/l	0.006	0.006	L 0.00
Inorganic Phosphorus (P) mg/l	0.007	0.008	L 0.00
Potassium (K) mg/l	2.2	2.4	2.7
Non Filterable Residue, mg/l	52.8	—	—
Fixed Residue, mg/l	1.2	—	—
Mercury (Hg) µg/l	0.09	0.12	0.12
Zinc (Zn) mg/l	L 0.001	L 0.002	0.00
Sodium (Na) mg/l	15.5	17.9	17.7
Silica (SiO_2) mg/l	1.5	1.5	1.0
Sulphate (SO_4) mg/l	28.7	32.3	34.9
Calcium (Ca) mg/l	37.6	35.3	37.0
Hardness Total ($CaCO_3$) mg/l	137.	146.	142.
Alkalinity Total ($CaCO_3$) mg/l	114.	125.	116.
Specific Conductance, micromho/cm	327.	337.	347.
Total Inorganic Carbon (C) mg/l	26.	26.	23.
Total Organic Carbon (C) mg/l	9.	10.	8.
Total Coliform (M.P.N.)	4.	0.	9.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER ● KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES March 25/73	May 3/73	June 4/73
Turbidity	6.2		4.4
Temperature (Field) °C	—	0.5	—
Temperature (Lab) °C	23.6	22.0	24.5
Colour	10.0	25.	15.
pH	8.0	8.2	8.2
Chloride (Cl) mg/l	17.2	17.5	12.1
Copper (Cu) mg/l	L 0.003	L 0.003	0.014
Fluoride (F) mg/l	0.09	0.08	L 0.05
Iron (Fe) mg/l	0.03	0.04	L 0.04
Lead (Pb) mg/l	—	L 0.002	L 0.005
Manganese (Mn) mg/l	L 0.008	L 0.006	L 0.005
Nitrogen T. Kjeldahl (N) mg/l	---	0.45	0.32
Nitrogen Nitrate, Nitrite (N) mg/l	0.07	0.15	0.04
Phosphorus Total (P) mg/l	—	—	0.015
Phosphorus Ortho (P) mg/l	0.005	0.005	L 0.003
Inorganic Phosphorus (P) mg/l	0.008	0.007	L 0.002
Potassium (K) mg/l	2.5	—	1.8
Non Filterable Residue, mg/l	—	0.8	—
Fixed Residue, mg/l	—	0.1	—
Mercury (Hg) µg/l	0.05	0.02	0.05
Zinc (Zn) mg/l	L 0.002	0.014	L 0.002
Sodium (Na) mg/l	16.7	17.8	12.3
Silica (SiO_2) mg/l	1.7	1.2	1.0
Sulphate (SO_4) mg/l	30.1	30.3	22.
Calcium (Ca) mg/l	48.7	25.3	40.
Hardness Total ($CaCO_3$) mg/l	137.	139.	104.
Alkalinity Total ($CaCO_3$) mg/l	115.	114.	88.
Specific Conductance, micromho/cm	359.	361.	267.
Total Inorganic Carbon (C) mg/l	19.	17.	14.
Total Organic Carbon (C) mg/l	9.	10.	8.
Total Coliform (M.P.N.)	23.	0	3
Fecal Coliform (M.P.N.)	23	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES July 9/73	August 2/73	September 1./73
Turbidity	5.4	2.5	8.6
Temperature (Field) °C	16.1	—	—
Temperature (Lab) °C	25.8	22.6	20.5
Colour	10.	20.	30.
pH	8.2	7.8	8.2
Chloride (Cl) mg/l	13.	14.	16.
Copper (Cu) mg/l	0.013	0.005	0.017
Fluoride (F) mg/l	0.12	0.07	0.09
Iron (Fe) mg/l	L 0.04	L 0.04	0.03
Lead (Pb) mg/l	L 0.003	L 0.004	L 0.00
Manganese (Mn) mg/l	L 0.011	L 0.003	L 0.00
Nitrogen T. Kjeldahl (N) mg/l	—	0.4	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	L 0.01	0.06
Phosphorus Total (P) mg/l	0.015	0.014	—
Phosphorus Ortho (P) mg/l	0.003	0.005	—
Inorganic Phosphorus (P) mg/l	0.005	0.006	—
Potassium (K) mg/l	2.0	1.9	2.2
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.08	0.07	0.05
Zinc (Zn) mg/l	L 0.003	L 0.001	0.00
Sodium (Na) mg/l	13.	13.	16.
Silica (SiO_2) mg/l	1.4	1.4	2.7
Sulphate (SO_4) mg/l	24.	24.	24.
Calcium (Ca) mg/l	31.	37.	40.
Hardness Total ($CaCO_3$) mg/l	114.	114.	121.
Alkalinity Total ($CaCO_3$) mg/l	98.	98.	102.
Specific Conductance, micromho/cm	340.	279.	301.
Total Inorganic Carbon (C) mg/l	16.	16.	21.
Total Organic Carbon (C) mg/l	6.	8.	7.
Total Coliform (M.P.N.)	6.	—	23.
Fecal Coliform (M.P.N.)	—	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES October 11/73	November 8/73	January 10/74
Turbidity	5.4	7.0	13.
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	13.8	17.3	14.9
Colour	25.	30.	30.
pH	7.9	8.0	7.8
Chloride (Cl) mg/l	14.	14.	16.
Copper (Cu) mg/l	—	0.003	0.003
Fluoride (F) mg/l	0.1	0.09	0.09
Iron (Fe) mg/l	—	0.04	0.03
Lead (Pb) mg/l	—	L 0.009	L 0.004
Manganese (Mn) mg/l	—	L 0.009	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	0.8	0.5	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.02	0.09
Phosphorus Total (P) mg/l	0.005	0.011	—
Phosphorus Ortho (P) mg/l	0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.005	L 0.003	L 0.006
Potassium (K) mg/l	2.0	2.0	2.3
Non Filterable Residue, mg/l	L 0.1	—	—
Fixed Residue, mg/l	L 0.1	—	—
Mercury (Hg) µg/l	L 0.02	L 0.03	0.08
Zinc (Zn) mg/l	—	—	L 0.001
Sodium (Na) mg/l	15.	15.	17.
Silica (SiO_2) mg/l	2.6	2.5	1.5
Sulphate (SO_4) mg/l	22.	24.	28.
Calcium (Ca) mg/l	33.	33.	35.
Hardness Total ($CaCO_3$) mg/l	118.	126.	129.
Alkalinity Total ($CaCO_3$) mg/l	101.	107.	115.
Specific Conductance, micromho/cm	285.	309.	341.
Total Inorganic Carbon (C) mg/l	19.	20.	23.
Total Organic Carbon (C) mg/l	11.	10.	10.
Total Coliform (M.P.N.)	0.	0.	4
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES February 7/74	March 21/74	April 25/74
Turbidity	2.9	4.0	4.7
Temperature (Field) °C	0.6	0.6	—
Temperature (Lab) °C	18.8	21.7	20.9
Colour	10.	15.	20.
pH	7.9	7.8	7.9
Chloride (Cl) mg/l	18.	18.	19.
Copper (Cu) mg/l	0.001	0.001	L0.001
Fluoride (F) mg/l	0.10	0.10	0.08
Iron (Fe) mg/l	L 0.04	L 0.03	L 0.04
Lead (Pb) mg/l	L 0.003	0.002	L 0.004
Manganese (Mn) mg/l	L 0.02	L 0.010	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.08	0.07
Phosphorus Total (P) mg/l	0.013	—	—
Phosphorus Ortho (P) mg/l	L 0.003	0.004	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.006	L 0.003
Potassium (K) mg/l	2.4	2.4	2.3
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.02	L 0.05	0.07
Zinc (Zn) mg/l	0.004	L 0.001	L 0.001
Sodium (Na) mg/l	18.	17.	18.
Silica (SiO_2) mg/l	1.0	1.6	1.6
Sulphate (SO_4) mg/l	30.	29.	32.
Calcium (Ca) mg/l	35.	35.	34.
Hardness Total ($CaCO_3$) mg/l	137.	141.	135.
Alkalinity Total ($CaCO_3$) mg/l	117.	113.	115.
Specific Conductance, micromho/cm	354.	357.	352.
Total Inorganic Carbon (C) mg/l	17.	20.	24.
Total Organic Carbon (C) mg/l	7.	6.	8.
Total Coliform (M.P.N.)	4.	0.	0.
Fecal Coliform (M.P.N.)	4	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 9 NELSON RIVER AT KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES May 9/74	June 6/74	August 1/74
Turbidity	3.5	3.5	2.8
Temperature (Field) °C	--	--	--
Temperature (Lab) °C	19.1	24.2	18.4
Colour	30.	20.	5.
pH	7.8	8.0	7.8
Chloride (Cl) mg/l	18.	14.	19.
Copper (Cu) mg/l	0.017	0.016	0.004
Fluoride (F) mg/l	0.10	0.07	0.08
Iron (Fe) mg/l	L0.04	L0.040	0.05
Lead (Pb) mg/l	0.007	L0.004	L0.004
Manganese (Mn) mg/l	L0.010	L0.010	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.41	0.02	L0.01
Phosphorus Total (P) mg/l	L0.003	0.014	**
Phosphorus Ortho (P) mg/l	L0.003	L0.003	**
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	**
Potassium (K) mg/l	2.2	1.9	2.3
Non Filterable Residue, mg/l	--	L1.	--
Fixed Residue, mg/l	--	L1.	--
Mercury (Hg) µg/l	0.07	0.33	0.06
Zinc (Zn) mg/l	0.001	0.002	0.001
Sodium (Na) mg/l	17.	15.	17.
Silica (SiO_2) mg/l	1.6	0.8	1.0
Sulphate (SO_4) mg/l	27.	24.	25.
Calcium (Ca) mg/l	36.	28.	35.
Hardness Total ($CaCO_3$) mg/l	126.	110.	122.
Alkalinity Total ($CaCO_3$) mg/l	106.	94.	106.
Specific Conductance, micromho/cm	330.	283.	303.
Total Inorganic Carbon (C) mg/l	25.	21.	21.
Total Organic Carbon (C) mg/l	8.	10.	9.
Total Coliform (M.P.N.)	0.	0.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

** = no value: contamination

STATION# 9 NELSON RIVER @ KETTLE RAPIDS

CONSTITUENTS	SAMPLING DATES Sept. 3/74	Sept. 11/74	
Turbidity	6.3	5.0	
Temperature (Field) °C	14.4	--	
Temperature (Lab) °C	19.4	23.4	
Colour	10.	L5.	
pH	8.2	8.1	
Chloride (Cl) mg/l	20.	17.	
Copper (Cu) mg/l	0.011	--	
Fluoride (F) mg/l	0.08	0.10	
Iron (Fe) mg/l	L0.04	--	
Lead (Pb) mg/l	0.008	--	
Manganese (Mn) mg/l	L0.01	--	
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	0.01	0.01	
Phosphorus Total (P) mg/l	0.014	0.007	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	0.003	L0.003	
Potassium (K) mg/l	2.3	2.2	
Non Filterable Residue, mg/l	--	--	
Fixed Residue, mg/l	--	--	
Mercury (Hg) microgram/l	--	0.56	
Zinc (Zn) mg/l	0.001	--	
Sodium (Na) mg/l	17	17	
Silica (SiO_2) mg/l	1.8	1.4	
Sulphate (SO_4) mg/l	--	35	
Calcium (Ca) mg/l	31	31.	
Hardness Total ($CaCO_3$) mg/l	--	131	
Alkalinity Total ($CaCO_3$) mg/l	123	112	
Specific Conductance, micromho/cm	323	307	
Total Inorganic Carbon (C) mg/l	22	--	
Total Organic Carbon (C) mg/l	9	--	
Total Coliform (M.P.N.)	4		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #10 NELSON RIVER
@ Split Lake

CONSTITUENTS	SAMPLING DATES		
	July 13/72	Aug. 1/72	Sept. 6/72
Turbidity	28	28	35
Temperature (Field)°C	16.8	15.5	-
Temperature (Lab)°C	23.7	23.4	24.4
Colour	50	30	20
pH	8.1	7.9	7.7
Chloride (Cl) mg/l	13.0	14.2	16.6
Copper (Cu) mg/l	0.001	0.001	0.016
Fluoride (F) mg/l	0.09	0.08	0.08
Iron (Fe) mg/l	L0.01	0.12	0.20
Lead (Pb) mg/l	L0.004	L0.002	0.010
Manganese (Mn) mg/l	L0.01	L0.008	0.01
Nitrogen T. Kjeldahl (N) mg/l	0.54	0.85	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.90	1.1
Phosphorus Total (P) mg/l	0.053	0.044	0.05
Phosphorus Ortho (P) mg/l	0.003	0.004	L0.003
Inorganic Phosphorus (P) mg/l	0.006	0.007	0.00
Potassium (K) mg/l	1.8	1.7	2.2
Non Filterable Residue, mg/l	14.8	23.0	31.6
Fixed Residue, mg/l	4.8	11.0	25.2
Mercury (Hg) µg/l	0.06	0.08	1.1*
Zinc (Zn) mg/l	0.001	0.006	0.012
Sodium (Na) mg/l	11.8	12.8	14.8
Silica (SiO_2) mg/l	1.1	1.5	1.4
Sulphate (SO_4) mg/l	20.7	24.4	20.9
Calcium (Ca) mg/l	24.5	25.4	29.2
Hardness Total ($CaCO_3$) mg/l	98.5	101.0	111.0
Alkalinity Total ($CaCO_3$) mg/l	83,6	78.6	96.2
Specific Conductance, micromho/cm	256	247	296
Total Inorganic Carbon (C) mg/l	15	11	11
Total Organic Carbon (C) mg/l	10	12	11
Total Coliform (M.P.N.)	11	4	240
Fecal Coliform (M.P.N.)	-	0	23

LEGEND MPN = Most probable number per 100 ml
L = Less than
* = Preservative contaminated, unreliable value

STATION #10 Nelson River
@ Split Lake

CONSTITUENTS	SAMPLING DATES Oct. 11/72	Nov. 13/72	Dec. 5/72
Turbidity	24	20	14
Temperature (Field) °C	-	-	0.5
Temperature (Lab) °C	22.6	21.8	21.3
Colour	30	30	30
pH	8.0	8.2	8.2
Chloride (Cl) mg/l	13.2	13.9	21.4
Copper (Cu) mg/l	L0.002	0.003	0.004
Fluoride (F) mg/l	0.06	0.06	0.08
Iron (Fe) mg/l	L0.04	0.01	0.01
Lead (Pb) mg/l	L0.008	L0.005	0.006
Manganese (Mn) mg/l	L0.008	L0.010	0.010
Nitrogen T. Kjeldahl (N) mg/l	0.57	0.87	1.24
Nitrogen Nitrate, Nitrite (N) mg/l	0.54	L0.01	0.58
Phosphorus Total (P) mg/l	0.036	0.034	0.025
Phosphorus Ortho (P) mg/l	0.003	0.004	0.003
Inorganic Phosphorus (P) mg/l	0.004	0.004	0.008
Potassium (K) mg/l	1.7	2.3	3.9
Non Filterable Residue, mg/l	4.4	12.0	10.0
Fixed Residue, mg/l	1.6	11.2	5.2
Mercury (Hg) µg/l	0.58	0.27	0.09
Zinc (Zn) mg/l	0.002	0.003	0.002
Sodium (Na) mg/l	13.3	14.4	21.2
Silica (SiO_2) mg/l	1.4	1.6	1.2
Sulphate (SO_4) mg/l	24.1	24.8	33.9
Calcium (Ca) mg/l	32.4	39.3	46.4
Hardness Total ($CaCO_3$) mg/l	115	126	168
Alkalinity Total ($CaCO_3$) mg/l	97.3	110	145
Specific Conductance, micromho/cm	283	320	445
Total Inorganic Carbon (C) mg/l	18	24	32
Total Organic Carbon (C) mg/l	9	12	14
Total Coliform (M.P.N.)	15	43	9
Fecal Coliform (M.P.N.)	0	23	0

LEGEND MPN = Most probable number per 100 ml
L = Less than

STATION # 10 NELSON RIVER
@ Split Lake

CONSTITUENTS	SAMPLING DATES Dec. 6/72	Jan. 2/73	March 1/73
Turbidity	18	13	5.6
Temperature (Field) °C	-	0	0
Temperature (Lab) °C	22.8	25	23.2
Colour	30	20	10
pH	8.3	7.9	8.2
Chloride (Cl) mg/l	15.2	15.8	17.9
Copper (Cu) mg/l	0.002	L0.001	0.002
Fluoride (F) mg/l	0.09	0.08	0.10
Iron (Fe) mg/l	L0.01	0.06	-
Lead (Pb) mg/l	L0.006	L0.008	L0.005
Manganese (Mn) mg/l	L0.005	L0.006	0.008
Nitrogen T. Kjeldahl (N) mg/l	0.63	0.78	0.53
Nitrogen Nitrate, Nitrite (N) mg/l	0.34	0.85	0.10
Phosphorus Total (P) mg/l	-	—	L0.003
Phosphorus Ortho (P) mg/l	0.005	0.007	L0.003
Inorganic Phosphorus (P) mg/l	0.007	0.007	L0.003
Potassium (K) mg/l	2.3	2.2	2.8
Non Filterable Residue, mg/l	10.0	10.0	-
Fixed Residue, mg/l	7.6	3.2	-
Mercury (Hg) µg/l	19*	0.36	0.19
Zinc (Zn) mg/l	L0.001	L0.001	0.004
Sodium (Na) mg/l	15.4	15.8	11.6
Silica (SiO_2) mg/l	1.4	1.8	1.0
Sulphate (SO_4) mg/l	-	29.7	31.7
Calcium (Ca) mg/l	34.4	38.2	39.5
Hardness Total ($CaCO_3$) mg/l	134	133	145
Alkalinity Total ($CaCO_3$) mg/l	117	113	120
Specific Conductance, micromho/cm	339	345	348
Total Inorganic Carbon (C) mg/l	26	24	22
Total Organic Carbon (C) mg/l	9	11	8
Total Coliform (M.P.N.)	15	4	4
Fecal Coliform (M.P.N.)	7	0	0

LEGEND MPN = Most probable number per 100 ml
L = Less than
* = Preservative contaminated, unreliable value

STATION #10 NELSON RIVER
@ Split Lake

CONSTITUENTS	SAMPLING DATES March 25/73	July 10/73	July 10/73
Turbidity	6.5	10.5	7.7
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	23.6	24.0	24.0
Colour	15	18	20
pH	7.9	8.1	7.9
Chloride (Cl) mg/l	17.2	12.8	12
Copper (Cu) mg/l	L0.003	0.006	0.004
Fluoride (F) mg/l	0.09	0.10	0.09
Iron (Fe) mg/l	0.02	L0.04	L0.04
Lead (Pb) mg/l	-	L0.002	L0.002
Manganese (Mn) mg/l	L0.008	L0.011	L0.004
Nitrogen T. Kjeldahl (N) mg/l	-	0.48	0.51
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.12	0.36
Phosphorus Total (P) mg/l	0.019	0.020	0.05
Phosphorus Ortho (P) mg/l	0.008	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.008	0.006	0.003
Potassium (K) mg/l	2.5	2.1	2.0
Non Filterable Residue, mg/l	-	-	—
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	L0.05	L0.04	0.30
Zinc (Zn) mg/l	L0.002	0.004	0.003
Sodium (Na) mg/l	16.9	12.8	12
Silica (SiO_2) mg/l	1.3	1.6	1.5
Sulphate (SO_4) mg/l	32.2	22	20
Calcium (Ca) mg/l	36.4	29	32
Hardness Total ($CaCO_3$) mg/l	136	110	109
Alkalinity Total ($CaCO_3$) mg/l	114	95	94
Specific Conductance, micromho/cm	360	269	264
Total Inorganic Carbon (C) mg/l	22	15	14
Total Organic Carbon (C) mg/l	5	9	10
Total Coliform (M.P.N.)	4	-	-
Fecal Coliform (M.P.N.)	0	-	-

LEGEND MPN = Most probable number per 100 ml
L = Less than

STATION #10 NELSON RIVER
@ Split Lake

CONSTITUENTS	SAMPLING DATES July 10/ 73	Sept. 10/73	Oct. 16/73
Turbidity	14	7.6	5.3
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	26.0	21.6	25.0
Colour	20	30	20
pH	8.1	8.2	16
Chloride (Cl) mg/l	13.0	15	0.001
Copper (Cu) mg/l	L0.002	0.002	0.10
Fluoride (F) mg/l	0.07	0.08	L0.04
Iron (Fe) mg/l	L0.05	L0.02	0.008
Lead (Pb) mg/l	L0.004	L0.005	L0.010
Manganese (Mn) mg/l	0.30	L0.009	0.5
Nitrogen T. Kjeldahl (N) mg/l	0.16	-	0.07
Nitrogen Nitrate, Nitrite (N) mg/l	0.021	0.02	L0.003
Phosphorus Total (P) mg/l	0.005	-	L0.003
Phosphorus Ortho (P) mg/l	0.006	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	1.9	L0.003	2.2
Potassium (K) mg/l	-	2.1	-
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	L0.04	-	-
Mercury (Hg) µg/l	0.001	L0.02	0.001
Zinc (Zn) mg/l	12.3	0.003	16
Sodium (Na) mg/l	1.4	14	2.0
Silica (SiO_2) mg/l	28	3.1	25
Sulphate (SO_4) mg/l	29	23	28
Calcium (Ca) mg/l	109	39	126
Hardness Total ($CaCO_3$) mg/l	94	116	108
Alkalinity Total ($CaCO_3$) mg/l	268	100	321
Specific Conductance, micromho/cm	15	286	20
Total Inorganic Carbon (C) mg/l	9	22	9
Total Organic Carbon (C) mg/l	240	7	4
Total Coliform (M.P.N.)	0	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 10 NELSON RIVER @ SPLIT LAKE

CONSTITUENTS	SAMPLING DATES		
	July 25/74		
Turbidity	2.5		
Temperature (Field)°C	22		
Temperature (Lab)°C	23.9		
Colour	L5		
pH	7.9		
Chloride (Cl) mg/l	17		
Copper (Cu) mg/l	L0.001		
Fluoride (F) mg/l	0.1		
Iron (Fe) mg/l	L0.04		
Lead (Pb) mg/l	L0.004		
Manganese (Mn) mg/l	L0.01		
Nitrogen T. Kjeldahl (N) mg/l	0.6		
Nitrogen Nitrate, Nitrite (N) mg/l	0.02		
Phosphorus Total (P) mg/l	0.005		
Phosphorus Ortho (P) mg/l	0.003		
Inorganic Phosphorus (P) mg/l	L0.003		
Potassium (K) mg/l	2.2		
Non Filterable Residue, mg/l			
Fixed Residue, mg/l			
Mercury (Hg) microgram/l	L0.05		
Zinc (Zn) mg/l	0.002		
Sodium (Na) mg/l	17		
Silica (SiO_2) mg/l	1.0		
Sulphate (SO_4) mg/l	32		
Calcium (Ca) mg/l	31		
Hardness Total ($CaCO_3$) mg/l	130		
Alkalinity Total ($CaCO_3$) mg/l	102		
Specific Conductance, micromho/cm	311		
Total Inorganic Carbon (C) mg/l	23		
Total Organic Carbon (C) mg/l	9		
Total Coliform (M.P.N.)	4		
Fecal Coliform (M.P.N.)	--		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES July 6/72	August 9/72	September 6/72
Turbidity	2.5	25.	15.
Temperature (Field) °C	17.2	—	—
Temperature (Lab) °C	22.8	23.2	25.5
Colour	40	30	10
pH	8.2	8.1	8.0
Chloride (Cl) mg/l	15.	16.	18.3
Copper (Cu) mg/l	0.006	0.002	0.002
Fluoride (F) mg/l	0.08	0.08	0.09
Iron (Fe) mg/l	0.02	0.06	0.06
Lead (Pb) mg/l	L 0.004	L 0.002	L 0.006
Manganese (Mn) mg/l	L 0.010	L 0.005	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.59	0.57	0.55
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.09	1.6
Phosphorus Total (P) mg/l	0.038	0.039	0.027
Phosphorus Ortho (P) mg/l	0.005	0.004	0.006
Inorganic Phosphorus (P) mg/l	0.008	0.005	0.007
Potassium (K) mg/l	2.2	1.9	2.3
Non Filterable Residue, mg/l	13.6	10.8	4.3
Fixed Residue, mg/l	8.0	6.0	3.3
Mercury (Hg) µg/l	0.08	0.2	1.29*
Zinc (Zn) mg/l	L 0.01	0.006	0.019
Sodium (Na) mg/l	13.4	14.1	15.8
Silica (SiO_2) mg/l	0.8	1.6	1.4
Sulphate (SO_4) mg/l	23.0	23.4	26.4
Calcium (Ca) mg/l	29.2	24.7	30.3
Hardness Total ($CaCO_3$) mg/l	107.	104.	115.
Alkalinity Total ($CaCO_3$) mg/l	87.9	84.1	93.
Specific Conductance, micromho/cm	276	247	308
Total Inorganic Carbon (C) mg/l	13.	9.	14.
Total Organic Carbon (C) mg/l	13.	8.	11.
Total Coliform (M.P.N.)	240	9	4
Fecal Coliform (M.P.N.)	—	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES October 5/72	November 3/72	December 1/72
Turbidity	22.	21.	4.
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	23.0	21.2	22.6
Colour	20.	20.	20.
pH	8.2	8.0	7.9
Chloride (Cl) mg/l	16.0	15.0	23.2
Copper (Cu) mg/l	L 0.002	0.003	L 0.002
Fluoride (F) mg/l	0.08	0.09	0.05
Iron (Fe) mg/l	L 0.04	L 0.04	L 0.01
Lead (Pb) mg/l	L 0.008	L 0.005	L 0.005
Manganese (Mn) mg/l	L 0.008	L 0.010	0.056
Nitrogen T. Kjeldahl (N) mg/l	0.60	0.69	0.71
Nitrogen Nitrate, Nitrite (N) mg/l	0.55	0.41	4.4
Phosphorus Total (P) mg/l	0.035	0.032	0.007
Phosphorus Ortho (P) mg/l	0.003	0.005	L 0.003
Inorganic Phosphorus (P) mg/l	0.004	0.008	L 0.003
Potassium (K) mg/l	2.3	2.3	2.4
Non Filterable Residue, mg/l	4.8	11.2	—
Fixed Residue, mg/l	1.6	9.2	—
Mercury (Hg) µg/l	1.5	0.30	0.02
Zinc (Zn) mg/l	L 0.001	0.003	0.001
Sodium (Na) mg/l	15.7	15.1	15.3
Silica (SiO_2) mg/l	0.6	0.7	1.4
Sulphate (SO_4) mg/l	26.7	29.1	11.4
Calcium (Ca) mg/l	35.6	32.2	20.1
Hardness Total ($CaCO_3$) mg/l	120	134	87.5
Alkalinity Total ($CaCO_3$) mg/l	102	109	61.6
Specific Conductance, micromho/cm	309	326	252
Total Inorganic Carbon (C) mg/l	19	22	14
Total Organic Carbon (C) mg/l	8	9	8
Total Coliform (M.P.N.)	4	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES January 3/73	February 7/73	March 1/73
Turbidity	9.5	7.0	6.4
Temperature (Field) °C	—	0.0	0.0
Temperature (Lab) °C	25.	25.	23.2
Colour	20.	10.	10.
pH	8.1	8.0	8.3
Chloride (Cl) mg/l	21.0	21.6	18.3
Copper (Cu) mg/l	0.001	L 0.002	0.001
Fluoride (F) mg/l	0.08	0.08	0.10
Iron (Fe) mg/l	L 0.01	L 0.01	0.02
Lead (Pb) mg/l	L 0.008	0.003	—
Manganese (Mn) mg/l	0.067	0.10	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	0.87	0.77	0.39
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.57	0.18
Phosphorus Total (P) mg/l	—	—	0.40
Phosphorus Ortho (P) mg/l	L 0.003	0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.005	L 0.003
Potassium (K) mg/l	2.3	2.6	2.7
Non Filterable Residue, mg/l	6.4	4.0	—
Fixed Residue, mg/l	2.0	L 0.1	—
Mercury (Hg) µg/l	0.10	L 0.05	0.65
Zinc (Zn) mg/l	L 0.001	L 0.002	L .003
Sodium (Na) mg/l	16.3	18.0	17.9
Silica (SiO_2) mg/l	1.7	1.2	0.8
Sulphate (SO_4) mg/l	15.9	29.5	33.6
Calcium (Ca) mg/l	25.4	34.2	39.7
Hardness Total ($CaCO_3$) mg/l	97.2	114.	142.
Alkalinity Total ($CaCO_3$) mg/l	87.3	110.	117.
Specific Conductance, micromho/cm	270.	339.	348.
Total Inorganic Carbon (C) mg/l	19.	22.	23.
Total Organic Carbon (C) mg/l	6.	7.	8.
Total Coliform (M.P.N.)	0	0	4
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES March 25/73	May 3/73	June 1/73
Turbidity	5.5	17.	2.9
Temperature (Field)°C	—	0.5	—
Temperature (Lab)°C	23.6	24.8	24.0
Colour	10.	50.	10.
pH	7.8	8.5	8.3
Chloride (Cl) mg/l	18.5	16.8	15.8
Copper (Cu) mg/l	L 0.003	0.019	0.002
Fluoride (F) mg/l	0.10	0.08	0.06
Iron (Fe) mg/l	0.01	L 0.04	0.04
Lead (Pb) mg/l	—	L 0.002	L 0.005
Manganese (Mn) mg/l	L 0.008	L 0.023	0.007
Nitrogen T. Kjeldahl (N) mg/l	—	0.43	0.2[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.23	L 0.01
Phosphorus Total (P) mg/l	—	—	0.00[illegible]
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L0.003	L 0.003
Potassium (K) mg/l	2.7		2.0
Non Filterable Residue, mg/l	—	2.5	—
Fixed Residue, mg/l	—	0.5	—
Mercury (Hg) µg/l	0.05	0.02	L 0.03
Zinc (Zn) mg/l	0.006	0.004	L 0.002
Sodium (Na) mg/l	17.6	17.8	15.6
Silica (SiO_2) mg/l	1.1	1.4	0.8
Sulphate (SO_4) mg/l	30.0	28.6	22.9
Calcium (Ca) mg/l	35.1	24.3	37.0
Hardness Total ($CaCO_3$) mg/l	138.	128.	111.
Alkalinity Total ($CaCO_3$) mg/l	129.	112.	93.6
Specific Conductance, micromho/cm	369.	337.	296.
Total Inorganic Carbon (C) mg/l	18.	16.	14.
Total Organic Carbon (C) mg/l	8.	7.	8.
Total Coliform (M.P.N.)	0	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES July 6/73	August 2/73	September 13/73
Turbidity	5.8	3.2	4.7
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	26.0	22.4	20.7
Colour	20.	20.	25.
pH	8.5	8.5	8.1
Chloride (Cl) mg/l	19.	19.	14.
Copper (Cu) mg/l	0.006	0.005	0.003
Fluoride (F) mg/l	0.13	0.07	.08
Iron (Fe) mg/l	L 0.04	L 0.04	.02
Lead (Pb) mg/l	0.003	L 0.004	L .005
Manganese (Mn) mg/l	0.030	0.009	L .009
Nitrogen T. Kjeldahl (N) mg/l	—	—	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.05	.12
Phosphorus Total (P) mg/l	L 0.003	L 0.003	—
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	—
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	—
Potassium (K) mg/l	2.2	2.2	2.1
Non Filterable Residue, mg/l	2.0	—	—
Fixed Residue, mg/l	L 0.1	—	—
Mercury (Hg) µg/l	0.10	0.19	.06
Zinc (Zn) mg/l	L 0.003	L 0.001	.004
Sodium (Na) mg/l	16.	15.	14.
Silica (SiO_2) mg/l	1.4	1.2	2.9
Sulphate (SO_4) mg/l	21.	20.	22.
Calcium (Ca) mg/l	25.	29.	35.
Hardness Total ($CaCO_3$) mg/l	98.	95.	119.
Alkalinity Total ($CaCO_3$) mg/l	83.	85.	101.
Specific Conductance, micromho/cm	264.	255.	387.
Total Inorganic Carbon (C) mg/l	14.	14.	22.
Total Organic Carbon (C) mg/l	6.	6.	8.
Total Coliform (M.P.N.)	0.	—	7.
Fecal Coliform (M.P.N.)	—	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER AT KELSEY

CONSTITUENTS	SAMPLING DATES		
		Nov. 8/73	
Turbidity		5.1	
Temperature (Field)°C		0.6	
Temperature (Lab)°C		19.5	
Colour		45.	
pH		8.6	
Chloride (Cl) mg/l		14.	
Copper (Cu) mg/l		0.002	
Fluoride (F) mg/l		0.10	
Iron (Fe) mg/l		L0.02	
Lead (Pb) mg/l		L0.008	
Manganese (Mn) mg/l		L0.002	
Nitrogen T. Kjeldahl (N) mg/l		0.5	
Nitrogen Nitrate, Nitrite (N) mg/l		0.03	
Phosphorus Total (P) mg/l		-	
Phosphorus Ortho (P) mg/l		L0.003	
Inorganic Phosphorus (P) mg/l		L0.003	
Potassium (K) mg/l		2.0	
Non Filterable Residue, mg/l		-	
Fixed Residue, mg/l		-	
Mercury (Hg) µg/l		L0.03	
Zinc (Zn) mg/l		0.008	
Sodium (Na) mg/l		16.	
Silica (SiO_2) mg/l		2.6	
Sulphate (SO_4) mg/l		21.	
Calcium (Ca) mg/l		27.	
Hardness Total ($CaCO_3$) mg/l		114.	
Alkalinity Total ($CaCO_3$) mg/l		98.	
Specific Conductance, micromho/cm		292.	
Total Inorganic Carbon (C) mg/l		18.	
Total Organic Carbon (C) mg/l		9.	
Total Coliform (M.P.N.)		0.	
Fecal Coliform (M.P.N.)		0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 NELSON RIVER @ KELSEY

CONSTITUENTS	SAMPLING DATES January 15/74	February 7/74	March 21/74
Turbidity	5.6	3.4	8.4
Temperature (Field)°C	—	.6	0.6
Temperature (Lab)°C	10.9	18.7	21.7
Colour	35	10	35.
pH	8.7	8.1	8.6
Chloride (Cl) mg/l	18	19	17.
Copper (Cu) mg/l	.003	.001	0.005
Fluoride (F) mg/l	.12	0.10	0.09
Iron (Fe) mg/l	L .04	L 0.04	0.14
Lead (Pb) mg/l	.004	L 0.003	0.003
Manganese (Mn) mg/l	.064	L 0.02	0.018
Nitrogen T. Kjeldahl (N) mg/l	.7	0.5	0.3
Nitrogen Nitrate, Nitrite (N) mg/l	.09	0.3	0.05
Phosphorus Total (P) mg/l	—	0.012	--
Phosphorus Ortho (P) mg/l	L .003	0.005	L0.003
Inorganic Phosphorus (P) mg/l	L .003	0.006	0.003
Potassium (K) mg/l	2.3	2.3	2.4
Non Filterable Residue, mg/l	—	—	--
Fixed Residue, mg/l	—	—	--
Mercury (Hg) µg/l	.03	L 0.02	L0.05
Zinc (Zn) mg/l	L .001	.014	L0.001
Sodium (Na) mg/l	18.	19.	18.
Silica (SiO_2) mg/l	1.6	1.1	2.4
Sulphate (SO_4) mg/l	23.	32.	28.
Calcium (Ca) mg/l	28.	35.	29.
Hardness Total ($CaCO_3$) mg/l	113.	136.	122.
Alkalinity Total ($CaCO_3$) mg/l	100.	117.	102.
Specific Conductance, micromho/cm	301.	361.	330.
Total Inorganic Carbon (C) mg/l	20.	21.	17.
Total Organic Carbon (C) mg/l	6.	8.	8.
Total Coliform (M.P.N.)	0	0	0.
Fecal Coliform (M.P.N.)	0	0	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 11 Nelson River at Kelsey

CONSTITUENTS	SAMPLING DATES April 25/74	May 9/74	June 6/74
Turbidity	3.5	6.5	8.5
Temperature (Field)°C	--	2.	
Temperature (Lab)°C	20.7	19.3	24.8
Colour	20.	60.	55.
pH	7.9	8.4	8.6
Chloride (Cl) mg/l	20.	18.	21.
Copper (Cu) mg/l	0.020	0.005	0.003
Fluoride (F) mg/l	0.09	0.10	0.07
Iron (Fe) mg/l	L 0.04	0.04	L 0.040
Lead (Pb) mg/l	L 0.004	0.005	L 0.004
Manganese (Mn) mg/l	L 0.010	0.043	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.17	0.02	0.03
Phosphorus Total (P) mg/l	--	--	0.005
Phosphorus Ortho (P) mg/l	L 0.003	0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.005	0.005	L 0.003
Potassium (K) mg/l	2.3	2.4	2.1
Non Filterable Residue, mg/l	i.s.	--	5.6
Fixed Residue, mg/l	i.s.	--	1.6
Mercury (Hg) µg/l	0.07	0.04	0.03
Zinc (Zn) mg/l	L 0.010	0.001	0.000
Sodium (Na) mg/l	19.	19.	17.
Silica (SiO_2) mg/l	1.4	1.5	0.9
Sulphate (SO_4) mg/l	33.	25.	23.
Calcium (Ca) mg/l	33.	28.	21.
Hardness Total ($CaCO_3$) mg/l	138.	116.	97.
Alkalinity Total ($CaCO_3$) mg/l	113.	104.	87.
Specific Conductance, micromho/cm	356.	314.	265.
Total Inorganic Carbon (C) mg/l	24.	23.	19.
Total Organic Carbon (C) mg/l	9.	6.	7.
Total Coliform (M.P.N.)	0.	9.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml.

L = Less than

i.s. = insufficient sample

STATION# 11 Nelson River at Kelsey

CONSTITUENTS	SAMPLING DATES July 30/74	Aug. 1/74	Aug. 27/74
Turbidity	1.4	27.	8.
Temperature (Field)°C	18.3	——	14.4
Temperature (Lab)°C	19.8	18.8	20.8
Colour	15.	20.	17.
pH	8.2	8.0	8.1
Chloride (Cl) mg/l	19.	20.	17.
Copper (Cu) mg/l	0.002	0.19	——
Fluoride (F) mg/l	0.08	0.08	0.09
Iron (Fe) mg/l	0.10	0.07	——
Lead (Pb) mg/l	L0.004	L0.004	——
Manganese (Mn) mg/l	0.050	L0.010	——
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.5	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.05	0.02
Phosphorus Total (P) mg/l	L0.003	0.020	0.019
Phosphorus Ortho (P) mg/l	L0.003	0.010	——
Inorganic Phosphorus (P) mg/l	L0.003	0.012	——
Potassium (K) mg/l	2.3	2.3	2.3
Non Filterable Residue, mg/l	——	i.s.	——
Fixed Residue, mg/l	——	i.s.	——
Mercury (Hg) ug/l	0.05	L0.05	——
Zinc (Zn) mg/l	0.001	0.001	——
Sodium (Na) mg/l	17.	18.	18.
Silica (SiO_2) mg/l	0.7	1.7	1.5
Sulphate (SO_4) mg/l	25.	27.	37.
Calcium (Ca) mg/l	30.	34.	35.
Hardness Total ($CaCO_3$) mg/l	122.	123.	138.
Alkalinity Total ($CaCO_3$) mg/l	106.	107.	113.
Specific Conductance, micromho/cm	304.	313.	336.
Total Inorganic Carbon (C) mg/l	22.	21.	20.
Total Organic Carbon (C) mg/l	8.	8.	7.
Total Coliform (M.P.N.)		0.	
Fecal Coliform (M.P.N.)		0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than
i.s. = Insufficient Sample

STATION# 11 NELSON RIVER AT KELSEY

CONSTITUENTS	SAMPLING DATES Sept. 3/74		
Turbidity	7.2		
Temperature (Field) °C	14.4		
Temperature (Lab) °C	19.3		
Colour	30.		
pH	8.5		
Chloride (Cl) mg/l	17.		
Copper (Cu) mg/l	0.005		
Fluoride (F) mg/l	0.08		
Iron (Fe) mg/l	L0.04		
Lead (Pb) mg/l	0.005		
Manganese (Mn) mg/l	0.016		
Nitrogen T. Kjeldahl (N) mg/l	0.4		
Nitrogen Nitrate, Nitrite (N) mg/l	0.02		
Phosphorus Total (P) mg/l	0.009		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	L0.003		
Potassium (K) mg/l	2.3		
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	--		
Mercury (Hg) microgram/l	--		
Zinc (Zn) mg/l	L0.001		
Sodium (Na) mg/l	18.		
Silica (SiO_2) mg/l	2.0		
Sulphate (SO_4) mg/l	35.		
Calcium (Ca) mg/l	33.		
Hardness Total ($CaCO_3$) mg/l	126.		
Alkalinity Total ($CaCO_3$) mg/l	114.		
Specific Conductance, micromho/cm	312.		
Total Inorganic Carbon (C) mg/l	21.		
Total Organic Carbon (C) mg/l	4.		
Total Coliform (M.P.N.)	0.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 12 NELSON RIVER
@ Sipiwesk Lake

CONSTITUENTS	SAMPLING DATES July 11/77	August 26/77	Sept. 27/77
Turbidity	22	19	23
Temperature (Field) °C	17	20	-
Temperature (Lab) °C	24.0	23.8	22
Colour	50	10	10
pH	8.1	8.1	8.1
Chloride (Cl) mg/l	15.0	19.0	17.3
Copper (Cu) mg/l	0.003	0.002	0.002
Fluoride (F) mg/l	0.08	0.08	0.09
Iron (Fe) mg/l	L0.01	0.12	0.09
Lead (Pb) mg/l	L0.004	0.008	L0.004
Manganese (Mn) mg/l	L0.01	0.02	L0.01
Nitrogen T. Kjeldahl (N) mg/l	0.77	0.52	0.43
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	-	0.1
Phosphorus Total (P) mg/l	0.036	0.024	0.04
Phosphorus Ortho (P) mg/l	0.003	0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.006	0.008	0.01
Potassium (K) mg/l	2.0	2.5	2.4
Non Filterable Residue, mg/l	23.2	-	14.4
Fixed Residue, mg/l	18.0	-	10.0
Mercury (Hg) µg/l	0.08	L0.04	0.18
Zinc (Zn) mg/l	0.001	0.001	0.02
Sodium (Na) mg/l	13.1	17	16
Silica (SiO_2) mg/l	0.9	1.6	1.3
Sulphate (SO_4) mg/l	22.1	27.3	26.1
Calcium (Ca) mg/l	28.0	36.6	34.5
Hardness Total ($CaCO_3$) mg/l	101	112	120
Alkalinity Total ($CaCO_3$) mg/l	82.4	103	102
Specific Conductance, micromho/cm	271	302	315
Total Inorganic Carbon (C) mg/l	11	14	14
Total Organic Carbon (C) mg/l	11	7	6
Total Coliform (M.P.N.)	4	0	15
Fecal Coliform (M.P.N.)	-	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = sample contaminated

STATION #12 NELSON RIVER
@ Sipiwesk Lake

CONSTITUENTS	SAMPLING DATES Dec. 6/72	Feb. 28/73	July 10/73
Turbidity	9.5	5	1.1
Temperature (Field)°C	-	0	-
Temperature (Lab)°C	22.0	22.8	26.0
Colour	30	20	10
pH	7.9	8.1	8.2
Chloride (Cl) mg/l	17.0	18.1	16.5
Copper (Cu) mg/l	0.002	0.002	0.002
Fluoride (F) mg/l	0.06	0.10	0.08
Iron (Fe) mg/l	L0.01	-	L0.05
Lead (Pb) mg/l	L0.006	-	L0.004
Manganese (Mn) mg/l	L0.005	L0.008	L0.009
Nitrogen T. Kjeldahl (N) mg/l	0.48	0.38	0.48
Nitrogen Nitrate, Nitrite (N) mg/l	6.6	0.07	L0.01
Phosphorus Total (P) mg/l	0.033	-	0.012
Phosphorus Ortho (P) mg/l	0.006	0.006	0.005
Inorganic Phosphorus (P) mg/l	0.007	0.007	0.005
Potassium (K) mg/l	2.4	2.6	2.2
Non Filterable Residue, mg/l	7.6	1.2	-
Fixed Residue, mg/l	4.4	L0.1	-
Mercury (Hg) µg/l	0.07	0.31	L0.04
Zinc (Zn) mg/l	L0.001	L0.001	L0.001
Sodium (Na) mg/l	16.8	17.7	15.3
Silica (SiO_2) mg/l	0.5	0.9	1.2
Sulphate (SO_4) mg/l	31.5	32.9	28
Calcium (Ca) mg/l	36.2	35.4	31
Hardness Total ($CaCO_3$) mg/l	134	189	119
Alkalinity Total ($CaCO_3$) mg/l	93.9	117	104
Specific Conductance, micromho/cm	354	345	324
Total Inorganic Carbon (C) mg/l	25	22	14
Total Organic Carbon (C) mg/l	9	7	9
Total Coliform (M.P.N.)	9	9	0
Fecal Coliform (M.P.N.)	0	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 12 NELSON RIVER AT SIPIWESK LAKE

CONSTITUENTS	SAMPLING DATES September 10/73	October 17/73	
Turbidity	6.5	5.8	
Temperature (Field) °C	—	—	
Temperature (Lab) °C	21.6	19.3	
Colour	20.	15.	
pH	8.2	8.0	
Chloride (Cl) mg/l	17.	17.	
Copper (Cu) mg/l	L 0.001	L 0.001	
Fluoride (F) mg/l	0.08	0.10	
Iron (Fe) mg/l	L 0.02	L 0.04	
Lead (Pb) mg/l	L 0.005	L 0.008	
Manganese (Mn) mg/l	L 0.009	L 0.010	
Nitrogen T. Kjeldahl (N) mg/l	—	0.7	
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.02	
Phosphorus Total (P) mg/l	—	L 0.003	
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	
Potassium (K) mg/l	2.3	2.4	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) µg/l	0.02	0.04	
Zinc (Zn) mg/l	0.001	0.003	
Sodium (Na) mg/l	16.	18.	
Silica (SiO_2) mg/l	2.7	2.1	
Sulphate (SO_4) mg/l	26.	28.	
Calcium (Ca) mg/l	41.	35.	
Hardness Total ($CaCO_3$) mg/l	120.	125.	
Alkalinity Total ($CaCO_3$) mg/l	102.	110.	
Specific Conductance, micromho/cm	302.	332.	
Total Inorganic Carbon (C) mg/l	23.	19.	
Total Organic Carbon (C) mg/l	6.	9.	
Total Coliform (M.P.N.)	4.	0	
Fecal Coliform (M.P.N.)	0	0	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 12 NELSON RIVER AT SIPIWESK LAKE

CONSTITUENTS	SAMPLING DATES July 22/74		
Turbidity	7.7		
Temperature (Field)°C	21.7		
Temperature (Lab)°C	23.2		
Colour	5.		
pH	7.9		
Chloride (Cl) mg/l	18.		
Copper (Cu) mg/l	.003		
Fluoride (F) mg/l	.09		
Iron (Fe) mg/l	.08		
Lead (Pb) mg/l	L .004		
Manganese (Mn) mg/l	.017		
Nitrogen T. Kjeldahl (N) mg/l	.6		
Nitrogen Nitrate, Nitrite (N) mg/l	.08		
Phosphorus Total (P) mg/l	.012		
Phosphorus Ortho (P) mg/l	L .003		
Inorganic Phosphorus (P) mg/l	.003		
Potassium (K) mg/l	2.4		
Non Filterable Residue, mg/l	8		
Fixed Residue, mg/l	8		
Mercury (Hg) microgram/l	L .05		
Zinc (Zn) mg/l	.001		
Sodium (Na) mg/l	19.		
Silica (SiO_2) mg/l	.8		
Sulphate (SO_4) mg/l	30.		
Calcium (Ca) mg/l	33.		
Hardness Total ($CaCO_3$) mg/l	125.		
Alkalinity Total ($CaCO_3$) mg/l	105.		
Specific Conductance, micromho/cm	308.		
Total Inorganic Carbon (C) mg/l	24.		
Total Organic Carbon (C) mg/l	9.		
Total Coliform (M.P.N.)	0		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES August 2/72	September 1/72	September 27/72
Turbidity	20.	19.	21.
Temperature (Field)°C	1[illegible]	—	—
Temperature (Lab)°C	23.0	22.7	22.
Colour	30.	20.	20.
pH	7.9	8.1	8.4
Chloride (Cl) mg/l	13.8	17.8	17.3
Copper (Cu) mg/l	0.001	0.004	—
Fluoride (F) mg/l	0.08	0.08	0.09
Iron (Fe) mg/l	0.32	0.16	0.06
Lead (Pb) mg/l	0.003	L 0.005	—
Manganese (Mn) mg/l	L 0.005	L 0.005	—
Nitrogen T. Kjeldahl (N) mg/l	0.57	0.98	0.54
Nitrogen Nitrate, Nitrite (N) mg/l	0.84	1.8	0.97
Phosphorus Total (P) mg/l	0.046	0.038	0.029
Phosphorus Ortho (P) mg/l	0.003	0.006	0.003
Inorganic Phosphorus (P) mg/l	0.005	0.009	0.009
Potassium (K) mg/l	2.1	2.2	2.3
Non Filterable Residue, mg/l	11.2	8.8	11.2
Fixed Residue, mg/l	6.8	6.4	L 0.1
Mercury (Hg) µg/l	L 0.06	L 0.04	0.14
Zinc (Zn) mg/l	0.008	0.002	—
Sodium (Na) mg/l	13.2	16.2	15.4
Silica (SiO_2) mg/l	1.8	1.8	1.3
Sulphate (SO_4) mg/l	22.0	28.5	26.7
Calcium (Ca) mg/l	24.1	29.7	31.2
Hardness Total ($CaCO_3$) mg/l	99.5	114.	117.
Alkalinity Total ($CaCO_3$) mg/l	79.7	86.6	98.3
Specific Conductance, micromho/cm	249.	303.	314.
Total Inorganic Carbon (C) mg/l	8.0	13.	13.
Total Organic Carbon (C) mg/l	8.0	10.	14.
Total Coliform (M.P.N.)	23.	460.	93.
Fecal Coliform (M.P.N.)	23.	43.	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES		
	October 30/72	December 6/72	December 19/72
Turbidity	18.	9.4	15.
Temperature (Field)°C	—	—	0
Temperature (Lab)°C	22.6	23.1	24.8
Colour	20.	25.	10.
pH	8.1	8.2	8.2
Chloride (Cl) mg/l	17.0	19.3	19.1
Copper (Cu) mg/l	0.002	0.003	0.002
Fluoride (F) mg/l	0.07	0.11	0.09
Iron (Fe) mg/l	L 0.03	L 0.01	0.01
Lead (Pb) mg/l	0.022	L 0.006	L 0.008
Manganese (Mn) mg/l	L 0.006	L 0.005	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.78	0.91	0.69
Nitrogen Nitrate, Nitrite (N) mg/l	0.46	0.05	0.42
Phosphorus Total (P) mg/l	0.033	0.025	0.041
Phosphorus Ortho (P) mg/l	0.004	L0.003	0.007
Inorganic Phosphorus (P) mg/l	0.005	0.003	0.009
Potassium (K) mg/l	2.2	2.6	2.8
Non Filtereble Residue, mg/l	3.2	—	9.2
Fixed Residue, mg/l	L 0.1	—	L 0.1
Mercury (Hg) µg/l	0.77	L 0.07	—
Zinc (Zn) mg/l	L 0.003	0.011	0.002
Sodium (Na) mg/l	16.3	19.5	19.
Silica (SiO_2) mg/l	0.8	0.7	1.3
Sulphate (SO_4) mg/l	28.5	33.6	34.6
Calcium (Ca) mg/l	34.3	41.8	42.3
Hardness Total ($CaCO_3$) mg/l	131.	145.	156.
Alkalinity Total ($CaCO_3$) mg/l	108.	121.	126.
Specific Conductance, micromho/cm	316.	357.	392.
Total Inorganic Carbon (C) mg/l	22.	26.	31.
Total Organic Carbon (C) mg/l	12.	11.	8.
Total Coliform (M.P.N.)	43.	36.	750.
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES January 31/73	January 31/73	May 9/73
Turbidity	25.	5.8	6.2
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	25.	25.	25.7
Colour	25.	10.	10.
pH	8.2	8.2	8.3
Chloride (Cl) mg/l	29.9	18.6	15.5
Copper (Cu) mg/l	0.005	0.002	L 0.003
Fluoride (F) mg/l	0.07	0.09	L 0.05
Iron (Fe) mg/l	0.02	0.01	0.04
Lead (Pb) mg/l	L 0.002	L 0.002	L 0.002
Manganese (Mn) mg/l	L 0.008	L 0.008	0.013
Nitrogen T. Kjeldahl (N) mg/l	—	—	0.41
Nitrogen Nitrate, Nitrite (N) mg/l	0.15	0.37	0.01
Phosphorus Total (P) mg/l	0.042	0.020	0.031
Phosphorus Ortho (P) mg/l	L 0.003	0.003	0.003
Inorganic Phosphorus (P) mg/l	0.004	0.010	0.004
Potassium (K) mg/l	3.9	2.4	3.3
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	0.04
Zinc (Zn) mg/l	0.005	L 0.001	0.001
Sodium (Na) mg/l	25.1	17.8	16.8
Silica (SiO_2) mg/l	1.8	1.0	0.5
Sulphate (SO_4) mg/l	45.9	33.1	29.1
Calcium (Ca) mg/l	51.8	36.5	33.1
Hardness Total ($CaCO_3$) mg/l	191.	135.	124.0
Alkalinity Total ($CaCO_3$) mg/l	163.	117.	106.
Specific Conductance, micromho/cm	466.	341.	326.
Total Inorganic Carbon (C) mg/l	31.	22.	16.0
Total Organic Carbon (C) mg/l	14.	7.	5.0
Total Coliform (M.P.N.)	20.	1100.	9.
Fecal Coliform (M.P.N.)	0	0	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES June 12/73	July 16/73	September 6/73
Turbidity	14.	1.3	8.1
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	26.4	24.	21.6
Colour	30.	25.	30.
pH	8.2	8.2	8.2
Chloride (Cl) mg/l	14.	1.2	16.
Copper (Cu) mg/l	0.004	L 0.002	L 0.001
Fluoride (F) mg/l	0.08	L 0.07	0.08
Iron (Fe) mg/l	0.05	L 0.05	L 0.02
Lead (Pb) mg/l	L 0.005	L 0.004	L 0.005
Manganese (Mn) mg/l	L 0.006	L 0.008	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	0.53	0.59	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.03	0.02
Phosphorus Total (P) mg/l	0.28	0.017	—
Phosphorus Ortho (P) mg/l	0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.003	L 0.003	L 0.003
Potassium (K) mg/l	2.0	1.9	2.1
Non Filterable Residue, mg/l	—	L 0.1	—
Fixed Residue, mg/l	—	L 0.1	—
Mercury (Hg) µg/l	L 0.02	0.08	L 0.02
Zinc (Zn) mg/l	L 0.002	L 0.001	0.002
Sodium (Na) mg/l	13.	14.	16.
Silica (SiO_2) mg/l	1.3	1.6	2.3
Sulphate (SO_4) mg/l	22.3	34.	24.
Calcium (Ca) mg/l	30.7	29.	33.
Hardness Total ($CaCO_3$) mg/l	109.	108.	112.
Alkalinity Total ($CaCO_3$) mg/l	92.5	92.	95.
Specific Conductance, micromho/cm	285.	272.	286.
Total Inorganic Carbon (C) mg/l	14.	19.	19.
Total Organic Carbon (C) mg/l	7.	9.	8.
Total Coliform (M.P.N.)	15.	43.	23.
Fecal Coliform (M.P.N.)	15.	4.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES October 17/73	November 21/73	December 0/7
Turbidity	6.8	4.8	3.3
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	21.8	15.3	17.6
Colour	15.	25.	45.
pH	7.7	7.9	7.0
Chloride (Cl) mg/l	15.	17.	1.5
Copper (Cu) mg/l	0.001	0.003	L 0.00
Fluoride (F) mg/l	—	0.12	0.06
Iron (Fe) mg/l	L 0.04	L 0.02	0.25
Lead (Pb) mg/l	L 0.008	L 0.008	L 0.00
Manganese (Mn) mg/l	L 0.01	L 0.009	L 0.0
Nitrogen T. Kjeldahl (N) mg/l	0.6	0.7	0.9
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.11	0.08
Phosphorus Total (P) mg/l	0.011	L 0.003	0.01
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.0 3
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	0.00
Potassium (K) mg/l	2.2	2.3	0.7
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	0.06	L 0.02	0.04
Zinc (Zn) mg/l	0.002	0.007	0.00
Sodium (Na) mg/l	16.	18.	3.4
Silica (SiO_2) mg/l	1.8	1.8	4.3
Sulphate (SO_4) mg/l	38.	32.	3.4
Calcium (Ca) mg/l	35.	36.	21.
Hardness Total ($CaCO_3$) mg/l	127.	137.	87.
Alkalinity Total ($CaCO_3$) mg/l	102.	108.	80.
Specific Conductance, micromho/cm	327.	340.	163.
Total Inorganic Carbon (C) mg/l	13.	20.	18.
Total Organic Carbon (C) mg/l	7.	10.	16.
Total Coliform (M.P.N.)	0	—	0
Fecal Coliform (M.P.N.)	0	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES January 29/74	February 18/74	March 25/74
Turbidity	3.5	2.4	2.4
Temperature (Field)°C	—	-	--
Temperature (Lab)°C	15.0	22.7	21.5
Colour	10.	10.	10.
pH	7.7	7.8	7.8
Chloride (Cl) mg/l	17.	18.	18.
Copper (Cu) mg/l	0.002	0.005	0.002
Fluoride (F) mg/l	0.11	0.12	0.10
Iron (Fe) mg/l	0.13	L0.04	0.10
Lead (Pb) mg/l	L 0.003	0.005	0.003
Manganese (Mn) mg/l	L 0.02	L0.02	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.6	0.4	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.40	0.05
Phosphorus Total (P) mg/l	0.015	0.013	0.013
Phosphorus Ortho (P) mg/l	0.005	0.007	L0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.006	L0.003
Potassium (K) mg/l	2.5	2.4	2.4
Non Filterable Residue, mg/l	—	-	--
Fixed Residue, mg/l	—	-	--
Mercury (Hg) µg/l	L 0.01	0.04	L0.05
Zinc (Zn) mg/l	0.006	0.002	0.001
Sodium (Na) mg/l	18.	18.	18.
Silica (SiO_2) mg/l	1.2	1.1	1.
Sulphate (SO_4) mg/l	30.	32.	31.
Calcium (Ca) mg/l	36.	34.	35.
Hardness Total ($CaCO_3$) mg/l	131.	148.	129.
Alkalinity Total ($CaCO_3$) mg/l	115.	113.	109.
Specific Conductance, micromho/cm	350.	348.	342.
Total Inorganic Carbon (C) mg/l	16.	21.	21.
Total Organic Carbon (C) mg/l	7.	10.	7.
Total Coliform (M.P.N.)	0	4.	4.
Fecal Coliform (M.P.N.)	0	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 13 Nelson River at Cross Lake (domestic water supply)

CONSTITUENTS	SAMPLING DATES April 16/74	May 2/74	June 13/74
Turbidity	2.8	4.	4.
Temperature (Field)°C	--		
Temperature (Lab)°C	21.5	22.4	24.3
Colour	5.	30.	20.
pH	8.2	7.8	7.9
Chloride (Cl) mg/l	13.	14.	16.
Copper (Cu) mg/l	0.004	0.002	0.002
Fluoride (F) mg/l	L 0.05	0.06	0.08
Iron (Fe) mg/l	L 0.03	L 0.040	L 0.040
Lead (Pb) mg/l	0.003	L 0.004	0.003
Manganese (Mn) mg/l	L 0.008	L 0.010	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.7	0.5	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.20	0.05	0.05
Phosphorus Total (P) mg/l	L 0.003	0.008	0.015
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	2.0	1.9	1.9
Non Filterable Residue, mg/l	--	i.s.	13.6
Fixed Residue, mg/l	--	i.s.	10.8
Mercury (Hg) µg/l	0.03	0.08	0.05
Zinc (Zn) mg/l	0.002	0.006	0.001
Sodium (Na) mg/l	13.	13.	14.
Silica (SiO_2) mg/l	0.8	0.8	1.3
Sulphate (SO_4) mg/l	22.	24.	23.
Calcium (Ca) mg/l	16.	27.	29.
Hardness Total ($CaCO_3$) mg/l	74.	98.	114.
Alkalinity Total ($CaCO_3$) mg/l	58.	87.	95.
Specific Conductance, micromho/cm	210	262.	277.
Total Inorganic Carbon (C) mg/l	9.	19.	21.
Total Organic Carbon (C) mg/l	8.	10.	9.
Total Coliform (M.P.N.)	0.	4.	4.
Fecal Coliform (M.P.N.)	0.	--	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 13 NELSON RIVER AT CROSS LAKE (DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES July 18/74	August 20/74	Sept. 17/74
Turbidity	3.5	8.5	4.6
Temperature (Field)°C			--
Temperature (Lab)°C	24.8	17.9	21.3
Colour	0	10	5
pH	7.	8.1	8.3
Chloride (Cl) mg/l	20.	18.	17.
Copper (Cu) mg/l	.037	0.002	0.001
Fluoride (F) mg/l	.07	0.09	0.1
Iron (Fe) mg/l	L .04	L0.04	0.06
Lead (Pb) mg/l	L .004	0.005	0.008
Manganese (Mn) mg/l	.016	L0.01	0.02
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.7	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.79	0.01	0.03
Phosphorus Total (P) mg/l	.012	0.016	0.016
Phosphorus Ortho (P) mg/l	L .003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	L .003	L0.003	L0.003
Potassium (K) mg/l	2.3	2.2	2.5
Non Filterable Residue, mg/l	4.	--	4.4
Fixed Residue, mg/l	L1.0	--	Fixed * non filterab L0.1
Mercury (Hg) microgram/l	L .05	L0.05	0.11
Zinc (Zn) mg/l	.001	0.003	0.005
Sodium (Na) mg/l	19.	18.	19.
Silica (SiO_2) mg/l	1.1	1.8	0.8
Sulphate (SO_4) mg/l	29.	37.	29.
Calcium (Ca) mg/l	31.	39.	30.
Hardness Total ($CaCO_3$) mg/l	125.	135.	130.
Alkalinity Total ($CaCO_3$) mg/l	102.	118.	117.
Specific Conductance, micromho/cm	305.	343.	341.
Total Inorganic Carbon (C) mg/l	22.	18.	23.
Total Organic Carbon (C) mg/l	11.	6.	8.
Total Coliform (M.P.N.)	9.	L 240.	0.
Fecal Coliform (M.P.N.)	0	--	0
Boron Dissolved		0.06	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 13 NELSON RIVER @ CROSS LAKE
(DOMESTIC WATER SUPPLY)

CONSTITUENTS	SAMPLING DATES Oct. 24, 1974	Nov. 20, 1974	Dec. 18, 197[illegible]
Turbidity	7.3		
Temperature (Field) °C	—		
Temperature (Lab) °C	21.8		
Colour	L5.		
pH	8.1		
Chloride (Cl) mg/l	18.		
Copper (Cu) mg/l	0.002		
Fluoride (F) mg/l	—		
Iron (Fe) mg/l	0.11		
Lead (Pb) mg/l	L0.004		
Manganese (Mn) mg/l	0.067		
Nitrogen T. Kjeldahl (N) mg/l	0.6		
Nitrogen Nitrate, Nitrite (N) mg/l	0.02		
Phosphorus Total (P) mg/l	0.019		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	L0.003		
Potassium (K) mg/l	2.4		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) micrograms/l	0.24		
Zinc (Zn) mg/l	L0.001		
Sodium (Na) mg/l	18.		
Silica (SiO_2) mg/l	0.6		
Sulphate (SO_4) mg/l	30.		
Calcium (Ca) mg/l	32.		
Hardness Total ($CaCO_3$) mg/l	137.		
Alkalinity Total ($CaCO_3$) mg/l	115.		
Specific Conductance, micromho/cm	334.		
Total Inorganic Carbon (C) mg/l	19.		
Total Organic Carbon (C) mg/l	8.		
Total Coliform (M.P.N.)	7.	0.	9.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES July 26, 1972	August 24/72	September 27/72
Turbidity	44	21	31
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	23.0	20.0	23.2
Colour	40.	20.	30.
pH	7.9	—	7.9
Chloride (Cl) mg/l	15.8	17.3	16.5
Copper (Cu) mg/l	0.002	0.003	L 0.00
Fluoride (F) mg/l	0.08	0.10	0.0
Iron (Fe) mg/l	L 0.05	0.38	0.0
Lead (Pb) mg/l	L 0.0	L 0.0	L 0.
Manganese (Mn) mg/l	L 0.005	L 0.020	0.0
Nitrogen T. Kjeldahl (N) mg/l	0.84	0.85	0.
Nitrogen Nitrate, Nitrite (N) mg/l	0.17	1.6	0.
Phosphorus Total (P) mg/l	0.074	0.027	--
Phosphorus Ortho (P) mg/l	—	0.003	L 0.00
Inorganic Phosphorus (P) mg/l	0.009	0.004	0.0
Potassium (K) mg/l	2.2	2.2	2.4
Non Filterable Residue, mg/l	28.0	12.0	23.2
Fixed Residue, mg/l	21.6	10.3	16.0
Mercury (Hg) µg/l	0.09	—	0.38
Zinc (Zn) mg/l	0.001	0.002	0.02
Sodium (Na) mg/l	14.6	16.0	16.0
Silica (SiO_2) mg/l	2.5	0.8	0.9
Sulphate (SO_4) mg/l	23.5	26.1	29.8
Calcium (Ca) mg/l	26.7	—	32.
Hardness Total ($CaCO_3$) mg/l	107.	--	119.
Alkalinity Total ($CaCO_3$) mg/l	87.9	—	106.
Specific Conductance, micromho/cm	293.	305.	320.
Total Inorganic Carbon (C) mg/l	16.	13.	15.
Total Organic Carbon (C) mg/l	14.	16.	12.
Total Coliform (M.P.N.)	4.	23.	23.
Fecal Coliform (M.P.N.)	4.	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES October 19/72	November 20/72	January 10/73
Turbidity	47	21	8.7
Temperature (Field)°C	—	—	0
Temperature (Lab)°C	23.8	21.3	26.
Colour	20.	20.	10.
pH	8.2	—	8.3
Chloride (Cl) mg/l	29.0	17.0	18.3
Copper (Cu) mg/l	0.003	0.001	L 0.002
Fluoride (F) mg/l	0.07	0.07	0.11
Iron (Fe) mg/l	0.09	0.01	L 0.01
Lead (Pb) mg/l	0.008	L 0.006	0.006
Manganese (Mn) mg/l	L 0.006	L 0.008	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.89	0.84	—
Nitrogen Nitrate, Nitrite (N) mg/l	4.0	0.07	0.40
Phosphorus Total (P) mg/l	0.008	0.027	0.021
Phosphorus Ortho (P) mg/l	L 0.003	0.004	0.004
Inorganic Phosphorus (P) mg/l	L 0.003	0.005	0.006
Potassium (K) mg/l	2.1	2.1	2.6
Non Filterable Residue, mg/l	—	20.8	3.2
Fixed Residue, mg/l	—	17.0	L 0.1
Mercury (Hg) µg/l	0.07	0.29	0.11
Zinc (Zn) mg/l	L 0.003	0.002	0.002
Sodium (Na) mg/l	25.4	16.7	18.1
Silica (SiO_2) mg/l	0.6	0.6	0.6
Sulphate (SO_4) mg/l	30.0	31.9	32.4
Calcium (Ca) mg/l	33.1	32.2	43.3
Hardness Total ($CaCO_3$) mg/l	131.	135.	143.
Alkalinity Total ($CaCO_3$) mg/l	109.	—	123.
Specific Conductance, micromho/cm	344.	342.	359.
Total Inorganic Carbon (C) mg/l	2.	19.	25.
Total Organic Carbon (C) mg/l	7.	12.	5.
Total Coliform (M.P.N.)	7.	9.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Unreliable value, contamination likely

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES January 24/73	February 19/73	April 2/73
Turbidity	6.6	6.1	6.6
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	24.5	23.0	21.0
Colour	15.	10.	15.
pH	8.1	8.3	8.2
Chloride (Cl) mg/l	18.3	18.2	17.8
Copper (Cu) mg/l	0.003	0.002	L 0.003
Fluoride (F) mg/l	0.07	0.10	0.10
Iron (Fe) mg/l	L 0.01	L 0.01	L 0.01
Lead (Pb) mg/l	L 0.004	L 0.003	L 0.004
Manganese (Mn) mg/l	L 0.006	L 0.004	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	0.43	—	0.32
Nitrogen Nitrate, Nitrite (N) mg/l	0.07	0.05	0.41
Phosphorus Total (P) mg/l	0.020	0.021	0.019
Phosphorus Ortho (P) mg/l	0.007	0.008	0.004
Inorganic Phosphorus (P) mg/l	0.008	0.009	0.006
Potassium (K) mg/l	2.4	2.6	2.6
Non Filterable Residue, mg/l	L 0.1	0.8	—
Fixed Residue, mg/l	L 0.1	L 0.1	—
Mercury (Hg) µg/l	0.19	0.29	0.06
Zinc (Zn) mg/l	0.003	0.002	0.002
Sodium (Na) mg/l	17.5	17.6	18.3
Silica (SiO_2) mg/l	0.6	0.6	0.8
Sulphate (SO_4) mg/l	31.8	33.4	30.4
Calcium (Ca) mg/l	35.0	42.7	43.1
Hardness Total ($CaCO_3$) mg/l	139.	141.	138.
Alkalinity Total ($CaCO_3$) mg/l	118.	117.	114.
Specific Conductance, micromho/cm	339.	349.	357.
Total Inorganic Carbon (C) mg/l	22.	26.	19.
Total Organic Carbon (C) mg/l	7.	7.	7.
Total Coliform (M.P.N.)	4.	0.	7.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES May 9/73	June 12/73	July 16/73
Turbidity	6.0	16.	16.
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	25.7	26.1	24.0
Colour	20.	20.	50.
pH	8.3	8.2	8.2
Chloride (Cl) mg/l	13.7	18.	16.
Copper (Cu) mg/l	L 0.003	0.004	0.003
Fluoride (F) mg/l	L0.05	0.09	0.07
Iron (Fe) mg/l	0.05	L 0.05	L 0.05
Lead (Pb) mg/l	L 0.002	L 0.005	L 0.00[illegible]
Manganese (Mn) mg/l	0.007	L 0.006	L 0.00[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.48	0.59	0.62
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.01	0.06
Phosphorus Total (P) mg/l	0.006	0.22	0.02[illegible]
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.003	L 0.003	L 0.003
Potassium (K) mg/l	1.9	2.3	2.2
Non Filterable Residue, mg/l	—	—	9.5
Fixed Residue, mg/l	—	—	2.5
Mercury (Hg) µg/l	0.04	L 0.02	0.08
Zinc (Zn) mg/l	L 0.001	L 0.002	0.003
Sodium (Na) mg/l	14.2	16.	16.
Silica (SiO_2) mg/l	0.7	0.8	1.3
Sulphate (SO_4) mg/l	23.6	27.9	28.
Calcium (Ca) mg/l	28.5	31.5	—
Hardness Total ($CaCO_3$) mg/l	104.	124.	—
Alkalinity Total ($CaCO_3$) mg/l	90.	105.	—
Specific Conductance, micromho/cm	280.	328.	303.
Total Inorganic Carbon (C) mg/l	11.	16.	22.
Total Organic Carbon (C) mg/l	9.	10.	11.
Total Coliform (M.P.N.)	4	4	4
Fecal Coliform (M.P.N.)	4	4	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES		
	September 5/73	October 17/73	November 21/73
Turbidity	7.5	17	14.
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	21.7	21.8	16.6
Colour	35.	20.	30.
pH	8.	8.0	8.2
Chloride (Cl) mg/l	17.	16.	18.
Copper (Cu) mg/l	L 0.001	0.002	0.004
Fluoride (F) mg/l	0.08	0.09	0.12
Iron (Fe) mg/l	L 0.02	L 0.04	L 0.02
Lead (Pb) mg/l	L 0.005	L 0.008	L 0.00
Manganese (Mn) mg/l	L 0.009	0.010	L 0.0
Nitrogen T. Kjeldahl (N) mg/l	0.01	0.7	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	—	0.02	0.0
Phosphorus Total (P) mg/l	—	0.007	0.0
Phosphorus Ortho (P) mg/l	—	L 0.003	L 0.0
Inorganic Phosphorus (P) mg/l	—	L 0.003	L 0.0
Potassium (K) mg/l	2.3	2.4	2.3
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.02	0.08	0.03
Zinc (Zn) mg/l	0.002	0.001	0.00
Sodium (Na) mg/l	17.	15.	19.
Silica (SiO_2) mg/l	2.0	2.1	1.0
Sulphate (SO_4) mg/l	26.	25.	32.
Calcium (Ca) mg/l	34.	35.	35.
Hardness Total ($CaCO_3$) mg/l	126.	131.	137.
Alkalinity Total ($CaCO_3$) mg/l	105.	111.	109.
Specific Conductance, micromho/cm	311.	334.	351.
Total Inorganic Carbon (C) mg/l	22.	21.	21.
Total Organic Carbon (C) mg/l	8.	8.	9.
Total Coliform (M.P.N.)	0		0
Fecal Coliform (M.P.N.)	0		0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES December 6/73	January 29/74	February 18/74
Turbidity	6.5	140(?)	14.
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	17.1	13.9	22.8
Colour	15.	20.	15.
pH	7.9	7.7	7.9
Chloride (Cl) mg/l	18.	19.	19.
Copper (Cu) mg/l	0.002	0.006	0.007
Fluoride (F) mg/l	0.06	0.11	0.11
Iron (Fe) mg/l	L 0.04	0.04	L 0.04
Lead (Pb) mg/l	L 0.004	0.005	L 0.003
Manganese (Mn) mg/l	L 0.008	L 0.02	L 0.02
Nitrogen T. Kjeldahl (N) mg/l	0.7	3.2	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	0.13	0.09	0.08
Phosphorus Total (P) mg/l	L 0.003	—	0.023
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	2.2	3.3	2.5
Non Filterable Residue, mg/l	—	—	14.
Fixed Residue, mg/l	—	—	4.5
Mercury (Hg) µg/l	L 0.03	0.05	0.02
Zinc (Zn) mg/l	0.002	L 0.002	0.012
Sodium (Na) mg/l	19.	20.	19.
Silica (SiO_2) mg/l	0.9	1.3	1.4
Sulphate (SO_4) mg/l	28.	34.	31.
Calcium (Ca) mg/l	42.	36.	36.
Hardness Total ($CaCO_3$) mg/l	135.	147.	136.
Alkalinity Total ($CaCO_3$) mg/l	113.	121.	115.
Specific Conductance, micromho/cm	342.	376.	360.
Total Inorganic Carbon (C) mg/l	24.	37.	24.
Total Organic Carbon (C) mg/l	8.	16.	7.
Total Coliform (M.P.N.)	—	9.	0
Fecal Coliform (M.P.N.)	—	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 14 Nelson River at Jenpeg

CONSTITUENTS	SAMPLING DATES March 25/74	April 16/74	May 21/74
Turbidity	3.2	3.5	4.
Temperature (Field)°C	--		
Temperature (Lab)°C	21.7	21.8	22.4
Colour	10.	10.	20.
pH	8.0	7.9	7.8
Chloride (Cl) mg/l	16.	20.	20.
Copper (Cu) mg/l	0.002	0.003	0.002
Fluoride (F) mg/l	0.10	0.09	0.08
Iron (Fe) mg/l	0.07	0.10	L 0.04
Lead (Pb) mg/l	0.003	0.006	L 0.004
Manganese (Mn) mg/l	L 0.010	L 0.005	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.4	--	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.14	0.07	0.11
Phosphorus Total (P) mg/l	--	L 0.003	0.007
Phosphorus Ortho (P) mg/l	0.004	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	0.005	L 0.003	L 0.003
Potassium (K) mg/l	2.1	2.5	2.2
Non Filterable Residue, mg/l	--	--	i.s.
Fixed Residue, mg/l	--	--	i.s.
Mercury (Hg) µg/l	L 0.05	L 0.03	0.06
Zinc (Zn) mg/l	L 0.001	0.002	L 0.001
Sodium (Na) mg/l	15.	19.	18.
Silica (SiO_2) mg/l	2.1	1.0	0.7
Sulphate (SO_4) mg/l	28.	30.	28.
Calcium (Ca) mg/l	35.	36.	30.
Hardness Total ($CaCO_3$) mg/l	139.	139.	122.
Alkalinity Total ($CaCO_3$) mg/l	121.	116.	107.
Specific Conductance, micromho/cm	360.	353.	335.
Total Inorganic Carbon (C) mg/l	23.	21.	24.
Total Organic Carbon (C) mg/l	7.	9.	8.
Total Coliform (M.P.N.)	0.	0.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s. = insufficient sample

STATION# 14 Nelson River at Jenpeg

CONSTITUENTS	SAMPLING DATES 18/06/74	18/07/74	20/08/74
Turbidity	5.0	8.4	23.
Temperature (Field) °C			
Temperature (Lab) °C	24.6	25.6	17.8
Colour	10.	5.	10.
pH	8.	8.0	8.4
Chloride (Cl) mg/l	19.	19.	18.
Copper (Cu) mg/l	0.003	0.004	0.002
Fluoride (F) mg/l	0.07	0.08	0.09
Iron (Fe) mg/l	0.10	0.22	L0.04
Lead (Pb) mg/l	L0.004	L0.004	L0.004
Manganese (Mn) mg/l	0.015	L0.01	L0.01
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.4	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.07	0.05
Phosphorus Total (P) mg/l	0.015	0.012	0.02
Phosphorus Ortho (P) mg/l	0.008	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	———	0.003	0.004
Potassium (K) mg/l	2.1	2.3	2.2
Non Filterable Residue, mg/l	———	1.0	———
Fixed Residue, mg/l	———	L1.0	———
Mercury (Hg) ug/l	L0.05	L0.05	L0.05
Zinc (Zn) mg/l	0.001	0.003	0.001
Sodium (Na) mg/l	17.	18.	18.
Silica (SiO_2) mg/l	0.7	1.	1.6
Sulphate (SO_4) mg/l	26.	29.	38.
Calcium (Ca) mg/l	30.	31.	34.
Hardness Total ($CaCO_3$) mg/l	120.	126.	135.
Alkalinity Total ($CaCO_3$) mg/l	101.	104.	116.
Specific Conductance, micromho/cm	315.	283.	347.
Total Inorganic Carbon (C) mg/l	23.	21.	18.
Total Organic Carbon (C) mg/l	8.	9.	11.
Total Coliform (M.P.N.)	0.	9.	L240.
Fecal Coliform (M.P.N.)	0.	0.	———

LECEND MPN = Most probable number per 100 ml

L = Less than

STATION# 14 NELSON RIVER @ JENPEG

CONSTITUENTS	SAMPLING DATES Sept. 17, 1974	Oct. 24, 1974	Nov. 20, 1974
Turbidity	19.	25.	
Temperature (Field)°C	—	—	
Temperature (Lab)°C	21.2	22.1	
Colour	10.	10.	
pH	8.4	8.2	
Chloride (Cl) mg/l	17.	19.	
Copper (Cu) mg/l	0.003	0.002	
Fluoride (F) mg/l	0.11	0.1	
Iron (Fe) mg/l	L0.04	0.17	
Lead (Pb) mg/l	0.010	L0.004	
Manganese (Mn) mg/l	L0.010	0.032	
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.5	
Nitrogen Nitrate, Nitrite (N) mg/l	0.01	0.03	
Phosphorus Total (P) mg/l	0.025	0.026	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	
Potassium (K) mg/l	2.5	2.4	
Non Filterable Residue, mg/l	14.	—	
Fixed Residue, mg/l Fixed* non-filterable	7.2	—	
Mercury (Hg) µg/l	0.14	0.16	
Zinc (Zn) mg/l	0.012	L0.001	
Sodium (Na) mg/l	19.	19.	
Silica (SiO_2) mg/l	0.4	0.4	
Sulphate (SO_4) mg/l	30.	31.	
Calcium (Ca) mg/l	35.	31.	
Hardness Total ($CaCO_3$) mg/l	133.	132.	
Alkalinity Total ($CaCO_3$) mg/l	120.	113.	
Specific Conductance, micromho/cm	339.	332.	
Total Inorganic Carbon (C) mg/l	23.	19.	
Total Organic Carbon (C) mg/l	9.	8.	
Total Coliform (M.P.N.)	0.	4.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 14 NELSON RIVER AT JENPEG

CONSTITUENTS	SAMPLING DATES		
	Dec. 18, 1974		
Turbidity			
Temperature (Field) °C			
Temperature (Lab) °C			
Colour			
pH			
Chloride (Cl) mg/l			
Copper (Cu) mg/l			
Fluoride (F) mg/l			
Iron (Fe) mg/l			
Lead (Pb) mg/l			
Manganese (Mn) mg/l			
Nitrogen T. Kjeldahl (N) mg/l			
Nitrogen Nitrate, Nitrite (N) mg/l			
Phosphorus Total (P) mg/l			
Phosphorus Ortho (P) mg/l			
Inorganic Phosphorus (P) mg/l			
Potassium (K) mg/l			
Non Filterable Residue, mg/l			
Fixed Residue, mg/l			
Mercury (Hg) µg/l			
Zinc (Zn) mg/l			
Sodium (Na) mg/l			
Silica (SiO_2) mg/l			
Sulphate (SO_4) mg/l			
Calcium (Ca) mg/l			
Hardness Total ($CaCO_3$) mg/l			
Alkalinity Total ($CaCO_3$) mg/l			
Specific Conductance, micromho/cm			
Total Inorganic Carbon (C) mg/l			
Total Organic Carbon (C) mg/l			
Total Coliform (M.P.N.)	0.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 15 NELSON RIVER
@ Norway House

CONSTITUENTS	SAMPLING DATES August 2/72	Sept. 7/72	Sept. 27/72
Turbidity	20	20	9.1
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	23.7	24.4	23.9
Colour	40	20	20
pH	8.0	7.5	7.9
Chloride (Cl) mg/l	14.3	17.7	17.1
Copper (Cu) mg/l	0.001	0.002	0.002
Fluoride (F) mg/l	0.09	0.08	0.11
Iron (Fe) mg/l	L0.05	L0.08	L0.02
Lead (Pb) mg/l	L0.002	L0.004	0.006
Manganese (Mn) mg/l	L0.008	L0.008	L0.00
Nitrogen T. Kjeldahl (N) mg/l	0.84	-	0.42
Nitrogen Nitrate, Nitrite (N) mg/l	0.07	0.17	0.11
Phosphorus Total (P) mg/l	0.042	0.033	0.02
Phosphorus Ortho (P) mg/l	L0.003	L0.003	0.00
Inorganic Phosphorus (P) mg/l	0.004	L0.003	0.00
Potassium (K) mg/l	1.7	2.1	2.3
Non Filterable Residue, mg/l	22.4	14.8	8.0
Fixed Residue, mg/l	14.4	8.4	-
Mercury (Hg) µg/l	0.06	0.39*	0.19*
Zinc (Zn) mg/l	0.003	0.002	0.02
Sodium (Na) mg/l	13.4	15.3	14.8
Silica (SiO_2) mg/l	3.2	1.5	0.8
Sulphate (SO_4) mg/l	23.6	26.0	29.2
Calcium (Ca) mg/l	28.1	28.9	30.2
Hardness Total ($CaCO_3$) mg/l	105	111	119
Alkalinity Total ($CaCO_3$) mg/l	86.1	96.3	105
Specific Conductance, micromho/cm	257	297	303
Total Inorganic Carbon (C) mg/l	18	11	13
Total Organic Carbon (C) mg/l	22	14	13
Total Coliform (M.P.N.)	93	-	23
Fecal Coliform (M.P.N.)	93	-	9

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = sample contaminated

STATION # 15 NELSON RIVER
@ Norway House

CONSTITUENTS	SAMPLING DATES Nov. 8/72	Nov. 14/72	Dec. 6/72
Turbidity	15	9.2	13.2
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	22	22.0	22.0
Colour	10	10	20
pH	8.3	8.2	8.2
Chloride (Cl) mg/l	17.0	16.2	18.0
Copper (Cu) mg/l	0.003	0.005	0.004
Fluoride (F) mg/l	0.05	0.05	0.07
Iron (Fe) mg/l	0.02	0.04	L0.01
Lead (Pb) mg/l	0.003	0.005	L0.0[illegible]
Manganese (Mn) mg/l	L0.10	L0.010	L0.0[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.74	1.49	1.0[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.40	0.48	0.1[illegible]
Phosphorus Total (P) mg/l	0.031	0.024	0.02[illegible]
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.0[illegible]
Inorganic Phosphorus (P) mg/l	L0.003	0.003	L0.00[illegible]
Potassium (K) mg/l	2.4	2.4	2.7
Non Filterable Residue, mg/l	12.4	8.8	4.8
Fixed Residue, mg/l	12.0	7.6	2.0
Mercury (Hg) µg/l	3.6*	0.07	L0.07
Zinc (Zn) mg/l	0.002	0.003	0.00[illegible]
Sodium (Na) mg/l	15.3	16.0	18.2
Silica (SiO_2) mg/l	0.4	0.4	0.5
Sulphate (SO_4) mg/l	22.6	21.2	32.2
Calcium (Ca) mg/l	31.0	37.5	34.6
Hardness Total ($CaCO_3$) mg/l	132	124	135
Alkalinity Total ($CaCO_3$) mg/l	105	108	118
Specific Conductance, micromho/cm	327	332	370
Total Inorganic Carbon (C) mg/l	23	17	27
Total Organic Carbon (C) mg/l	11	12	9
Total Coliform (M.P.N.)	11	7	-
Fecal Coliform (M.P.N.)	0	0	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = sample contaminated

STATION #15 NELSON RIVER
@ Norway House

CONSTITUENTS	SAMPLING DATES Jan. 8/73	March 13/73	April 4/73
Turbidity	6.3	6.8	3.3
Temperature (Field)°C	32	0.0	-
Temperature (Lab)°C	26	22.7	24.5
Colour	10	15	15
pH	7.8	8.1	8.1
Chloride (Cl) mg/l	18.2	18.0	17.8
Copper (Cu) mg/l	0.002	0.003	L0.003
Fluoride (F) mg/l	0.08	0.09	0.09
Iron (Fe) mg/l	L0.01	0.02	0.02
Lead (Pb) mg/l	L0.006	-	L0.001
Manganese (Mn) mg/l	L0.006	L0.008	L0.008
Nitrogen T. Kjeldahl (N) mg/l	32.2	1.08	0.46
Nitrogen Nitrate, Nitrite (N) mg/l	0.16	0.10	0.03
Phosphorus Total (P) mg/l	-	0.018	0.017
Phosphorus Ortho (P) mg/l	0.019	0.006	0.006
Inorganic Phosphorus (P) mg/l	0.020	0.009	0.007
Potassium (K) mg/l	2.3	2.4	2.4
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	0.11	0.39	0.04
Zinc (Zn) mg/l	0.001	0.003	0.002
Sodium (Na) mg/l	17.7	16.8	17.5
Silica (SiO_2) mg/l	0.6	1.2	0.7
Sulphate (SO_4) mg/l	32.4	29.2	29.4
Calcium (Ca) mg/l	35.4	30.7	33.4
Hardness Total ($CaCO_3$) mg/l	133	123	124
Alkalinity Total ($CaCO_3$) mg/l	112	104	103
Specific Conductance, micromho/cm	236	393	330
Total Inorganic Carbon (C) mg/l	24	20	20
Total Organic Carbon (C) mg/l	3	9	10
Total Coliform (M.P.N.)	4	4	75
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #15 NELSON RIVER
@ Norway House

CONSTITUENTS	SAMPLING DATES April 9/73	May 11/73	June 12/73
Turbidity	5.8	4.0	9.1
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	24.0	25.9	24.2
Colour	20	30	2.5
pH	8.2	8.3	8.2
Chloride (Cl) mg/l	17.0	10.9	13.0
Copper (Cu) mg/l	0.004	L0.003	0.002
Fluoride (F) mg/l	-	0.07	0.08
Iron (Fe) mg/l	0.03	0.09	0.05
Lead (Pb) mg/l	-	L0.002	0.005
Manganese (Mn) mg/l	0.066	0.009	0.006
Nitrogen T. Kjeldahl (N) mg/l	-	0.56	0.49
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.07	0.02
Phosphorus Total (P) mg/l	-	-	0.011
Phosphorus Ortho (P) mg/l	-	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	-	0.005	L0.003
Potassium (K) mg/l	2.2	1.7	2.0
Non Filterable Residue, mg/l	1.2	4.8	-
Fixed Residue, mg/l	L0.01	3.2	-
Mercury (Hg) µg/l	0.07	0.04	0.04
Zinc (Zn) mg/l	0.002	0.001	0.002
Sodium (Na) mg/l	16.8	11.2	13.0
Silica (SiO_2) mg/l	1.0	1.0	0.9
Sulphate (SO_4) mg/l	27.9	20.1	21.9
Calcium (Ca) mg/l	32.2	22.8	27.8
Hardness Total ($CaCO_3$) mg/l	122	866	104.0
Alkalinity Total ($CaCO_3$) mg/l	102	69.1	89.2
Specific Conductance, micromho/cm	320	231	271.0
Total Inorganic Carbon (C) mg/l	10.0	11	12.0
Total Organic Carbon (C) mg/l	18	8	10.0
Total Coliform (M.P.N.)	7	23	93
Fecal Coliform (M.P.N.)	0	0	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #15

CONSTITUENTS	SAMPLING DATES July 10/73	Sept. 10/73	Oct. 17/73
Turbidity	6.8	7.7	4.4
Temperature (Field) °C	-	16.0	-
Temperature (Lab) °C	24.0	19.8	20.8
Colour	30	20	25
pH	7.9	8.2	8.0
Chloride (Cl) mg/l	9.5	16	12
Copper (Cu) mg/l	L0.002	L0.001	L0.001
Fluoride (F) mg/l	0.06	0.09	0.08
Iron (Fe) mg/l	L0.04	0.02	L0.04
Lead (Pb) mg/l	L0.004	L0.005	L0.002
Manganese (Mn) mg/l	L0.009	L0.009	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.60	-	0.9
Nitrogen Nitrate, Nitrite (N) mg/l	0.11	0.20	0.04
Phosphorus Total (P) mg/l	0.023	-	L0.002
Phosphorus Ortho (P) mg/l	0.007	-	L0.003
Inorganic Phosphorus (P) mg/l	0.007	-	L0.002
Potassium (K) mg/l	1.4	2.1	1.8
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	0.04	0.02	0.05
Zinc (Zn) mg/l	L0.001	-	L0.002
Sodium (Na) mg/l	9.3	15	13
Silica (SiO_2) mg/l	1.6	2.0	2.2
Sulphate (SO_4) mg/l	22	24	21
Calcium (Ca) mg/l	23	33	31
Hardness Total ($CaCO_3$) mg/l	83	117	106
Alkalinity Total ($CaCO_3$) mg/l	70	100	93
Specific Conductance, micromho/cm	208	300	276
Total Inorganic Carbon (C) mg/l	15	20	16
Total Organic Carbon (C) mg/l	15	9	10
Total Coliform (M.P.N.)	43	4	4
Fecal Coliform (M.P.N.)	4	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 15 NELSON RIVER
@ Norway House

CONSTITUENTS	SAMPLING DATES Feb. 25/74	June 18/74	
Turbidity	2.8	3.	
Temperature (Field)°C	-	13.	
Temperature (Lab)°C	19.0	23.9	
Colour	10	20.	
pH	7.6	7.8	
Chloride (Cl) mg/l	20	16.	
Copper (Cu) mg/l	0.007	0.005	
Fluoride (F) mg/l	0.06	0.08	
Iron (Fe) mg/l	L0.04	L 0.04	
Lead (Pb) mg/l	0.002	0.007	
Manganese (Mn) mg/l	L0.02	L 0.010	
Nitrogen T. Kjeldahl (N) mg/l	1.5	0.6	
Nitrogen Nitrate, Nitrite (N) mg/l	0.13	0.04	
Phosphorus Total (P) mg/l	.047	0.012	
Phosphorus Ortho (P) mg/l	L0.003	0.003	
Inorganic Phosphorus (P) mg/l	L0.003	0.003	
Potassium (K) mg/l	2.8	2.0	
Non Filterable Residue, mg/l	-	——	
Fixed Residue, mg/l	-	——	
Mercury (Hg) ug/l	L0.03	L 0.05	
Zinc (Zn) mg/l	0.011	0.002	
Sodium (Na) mg/l	17	15.	
Silica (SiO_2) mg/l	1.1	0.7	
Sulphate (SO_4) mg/l	32	22.	
Calcium (Ca) mg/l	33	27.	
Hardness Total ($CaCO_3$) mg/l	130	108.	
Alkalinity Total ($CaCO_3$) mg/l	106	92.	
Specific Conductance, micromho/cm	346	283.	
Total Inorganic Carbon (C) mg/l	21	21.	
Total Organic Carbon (C) mg/l	12	6.	
Total Coliform (M.P.N.)	4		
Fecal Coliform (M.P.N.)	0		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 15 - NELSON RIVER @ NORWAY HOUSE

CONSTITUENTS	SAMPLING DATES July 22, 1974	August 1, 1974	Sept. 16, 1974
Turbidity	7.3	7.0	7.2
Temperature (Field)°C	21.1	--	10.8
Temperature (Lab)°C	23.3	18.3	21.2
Colour	10.	10.	5.
pH	7.7	7.8	8.4
Chloride (Cl) mg/l	14.	18.	17.
Copper (Cu) mg/l	.003	0.002	0.001
Fluoride (F) mg/l	.08	0.08	0.10
Iron (Fe) mg/l	.09	0.08	L0.04
Lead (Pb) mg/l	L.004	L0.004	0.009
Manganese (Mn) mg/l	L.01	0.022	L0.010
Nitrogen T. Kjeldahl (N) mg/l	.5	0.5	0.4
Nitrogen Nitrate, Nitrite (N) mg/l	.13	0.02	0.22
Phosphorus Total (P) mg/l	.01	**	0.012
Phosphorus Ortho (P) mg/l	L.003	**	L0.003
Inorganic Phosphorus (P) mg/l	L.003	**	L0.003
Potassium (K) mg/l	2.1	2.3	2.5
Non Filterable Residue, mg/l	7.	i.s.	2.8
Fixed Residue, mg/l	7.	i.s.	L0.1
Mercury (Hg) µg/l	L.05	L0.05	0.10
Zinc (Zn) mg/l	.001	0.004	0.002
Sodium (Na) mg/l	15.	18.	19.
Silica (SiO_2) mg/l	1.	1.3	0.5
Sulphate (SO_4) mg/l	27.	27.	32.
Calcium (Ca) mg/l	30.	31.	33.
Hardness Total ($CaCO_3$) mg/l	116.	125.	133.
Alkalinity Total ($CaCO_3$) mg/l	95.	108.	119.
Specific Conductance, micromho/cm	276.	308.	333.
Total Inorganic Carbon (C) mg/l	22.	23.	22.
Total Organic Carbon (C) mg/l	10.	8.	7.
Total Coliform (M.P.N.)	43.	150.	43.
Fecal Coliform (M.P.N.)	0.	7.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s.= insufficient sample

** = no values due to contamination

STATION # 16 NELSON RIVER @ WARREN LANDING

CONSTITUENTS	SAMPLING DATES September 6/72	January 30/73	March 13/73
Turbidity	35	4.3	6.5
Temperature (Field)°C	—	0	0
Temperature (Lab)°C	24.5	25.	24.8
Colour	20.	10.	10.
pH	7.5	8.1	8.2
Chloride (Cl) mg/l	36.	19.2	18.5
Copper (Cu) mg/l	0.003	0.003	L 0.003
Fluoride (F) mg/l	0.09	0.14	0.11
Iron (Fe) mg/l	0.42	L 0.012	0.02
Lead (Pb) mg/l	L 0.004	0.002	—
Manganese (Mn) mg/l	0.017	L 0.010	L 0.008
Nitrogen T. Kjeldahl (N) mg/l	—	—	0.76
Nitrogen Nitrate, Nitrite (N) mg/l	0.32	0.23	0.15
Phosphorus Total (P) mg/l	0.043	0.019	0.015
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.004
Inorganic Phosphorus (P) mg/l	L 0.003	0.003	0.004
Potassium (K) mg/l	4.8	2.8	2.9
Non Filterable Residue, mg/l	25.2	—	3.2
Fixed Residue, mg/l	18.	—	L 0.1
Mercury (Hg) µg/l	0.13	0.56	1.5 *
Zinc (Zn) mg/l	0.017	0.005	L 0.002
Sodium (Na) mg/l	24	19.8	19.2
Silica (SiO_2) mg/l	0.8	0.5	0.5
Sulphate (SO_4) mg/l	28.1	47.0	36.7
Calcium (Ca) mg/l	30.9	48.2	39.4
Hardness Total ($CaCO_3$) mg/l	125.	165.	162.
Alkalinity Total ($CaCO_3$) mg/l	95.	128.	136.
Specific Conductance, micromho/cm	317.	401.	412.
Total Inorganic Carbon (C) mg/l	11.	27.	24.
Total Organic Carbon (C) mg/l	8.	7.	7.
Total Coliform (M.P.N.)	9.	9.	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Suspected acid contamination in sample bottle.

STATION # 16 NELSON RIVER @ WARREN LANDING

CONSTITUENTS	SAMPLING DATES May 24/73	June 11/73	July 10/73
Turbidity	8.7	2.2	8.3
Temperature (Field) °C	3.3	—	—
Temperature (Lab) °C	25.8	24.	25.0
Colour	10.	0.	—
pH	8.3	8.3	8.3
Chloride (Cl) mg/l	17.8	16.	17.0
Copper (Cu) mg/l	0.003	0.003	L 0.002
Fluoride (F) mg/l	0.08	0.09	0.09
Iron (Fe) mg/l	L 0.03	0.05	0.04
Lead (Pb) mg/l	L 0.007	0.005	0.004
Manganese (Mn) mg/l	L 0.007	0.050	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	0.51	0.36	0.58
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	L 0.01	0.23
Phosphorus Total (P) mg/l	—	—	0.007
Phosphorus Ortho (P) mg/l	—	0.003	L 0.003
Inorganic Phosphorus (P) mg/l	—	0.003	L 0.003
Potassium (K) mg/l	2.4	2.4	2.3
Non Filterable Residue, mg/l	20.8	—	—
Fixed Residue, mg/l	17.2	—	—
Mercury (Hg) µg/l	—	0.04	L 0.04
Zinc (Zn) mg/l	0.002	0.002	0.001
Sodium (Na) mg/l	13.7	18.	16.7
Silica (SiO_2) mg/l	0.5	0.8	1.1
Sulphate (SO_4) mg/l	8.6	28.7	34
Calcium (Ca) mg/l	34.1	34.2	32.
Hardness Total ($CaCO_3$) mg/l	122.	127.	119.
Alkalinity Total ($CaCO_3$) mg/l	102.	107.	103.
Specific Conductance, micromho/cm	326.	336.	308.
Total Inorganic Carbon (C) mg/l	18.	17.	20.
Total Organic Carbon (C) mg/l	7.	7.	9.
Total Coliform (M.P.N.)	0.	0.	0.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 16 NELSON RIVER @ WARREN LANDING

CONSTITUENTS	SAMPLING DATES August 8/73	August 14/73	September 7/73
Turbidity	8.0	8.0	26.0
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	22.8	18.5	20.2
Colour	20.	25.	20.
pH	8.1	8.6	8.4
Chloride (Cl) mg/l	17.	15.	17.
Copper (Cu) mg/l	0.002	0.002	L 0.001
Fluoride (F) mg/l	0.09	0.09	0.09
Iron (Fe) mg/l	L 0.02	L 0.02	L 0.02
Lead (Pb) mg/l	L 0.004	L 0.004	L 0.005
Manganese (Mn) mg/l	L 0.009	L 0.009	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	0.2	0.4	0.2
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	—	—
Phosphorus Total (P) mg/l	—	0.004	—
Phosphorus Ortho (P) mg/l	—	—	—
Inorganic Phosphorus (P) mg/l	—	—	—
Potassium (K) mg/l	2.3	2.2	2.3
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.03	0.35	0.05
Zinc (Zn) mg/l	L 0.001	0.007	0.002
Sodium (Na) mg/l	16	16	18
Silica (SiO_2) mg/l	1.	1.3	1.8
Sulphate (SO_4) mg/l	25.	27.	28
Calcium (Ca) mg/l	30.	34.	32.
Hardness Total ($CaCO_3$) mg/l	116	117	131
Alkalinity Total ($CaCO_3$) mg/l	96	98	111
Specific Conductance, micromho/cm	296	298	324
Total Inorganic Carbon (C) mg/l	16	22	23
Total Organic Carbon (C) mg/l	7	9	7
Total Coliform (M.P.N.)	0	0	23
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 16 NELSON RIVER @ WARREN LANDING

CONSTITUENTS	SAMPLING DATES September 10/73	October 17/73	February 25/74
Turbidity	12.0	4.5	3.5
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	23.1	20.6	18.8
Colour	30.	10.	10.
pH	8.1	8.2	7.7
Chloride (Cl) mg/l	19.	17.	23.
Copper (Cu) mg/l	0.001	L 0.001	0.007
Fluoride (F) mg/l	0.08	0.10	0.13
Iron (Fe) mg/l	0.005	0.04	L 0.04
Lead (Pb) mg/l	L 0.005	L 0.008	L 0.002
Manganese (Mn) mg/l	L 0.009	L 0.010	L 0.02
Nitrogen T. Kjeldahl (N) mg/l	—	0.8	1.3
Nitrogen Nitrate, Nitrite (N) mg/l	—	0.02	0.07
Phosphorus Total (P) mg/l	—	L 0.003	—
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.012
Inorganic Phosphorus (P) mg/l	0.013	L 0.003	L 0.003
Potassium (K) mg/l	2.3	2.3	3.2
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.05	L 0.04	L 0.03
Zinc (Zn) mg/l	0.002	L 0.002	0.003
Sodium (Na) mg/l	18.	18.	21.
Silica (SiO_2) mg/l	—	1.0	0.9
Sulphate (SO_4) mg/l	30.	29.	40.
Calcium (Ca) mg/l	34.	36.	37.
Hardness Total ($CaCO_3$) mg/l	132.	130.	152.
Alkalinity Total ($CaCO_3$) mg/l	110.	112.	126.
Specific Conductance, micromho/cm	329.	340.	408.
Total Inorganic Carbon (C) mg/l	20.	19.	23.
Total Organic Carbon (C) mg/l	8.	8.	11.
Total Coliform (M.P.N.)	23.	0.	0.
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 16 NELSON RIVER AT WARREN LANDING

CONSTITUENTS	SAMPLING DATES		
	June 18, 1974		
Turbidity	5.5		
Temperature (Field) °C			
Temperature (Lab) °C	23.6		
Colour	20.		
pH	7.9		
Chloride (Cl) mg/l	19.		
Copper (Cu) mg/l	0.003		
Fluoride (F) mg/l	0.10		
Iron (Fe) mg/l	L0.04		
Lead (Pb) mg/l	0.004		
Manganese (Mn) mg/l	L0.010		
Nitrogen T. Kjeldahl (N) mg/l	0.6		
Nitrogen Nitrate, Nitrite (N) mg/l	0.10		
Phosphorus Total (P) mg/l	0.014		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	0.003		
Potassium (K) mg/l	2.3		
Non Filterable Residue, mg/l	7.6		
Fixed Residue, mg/l	6.0		
Mercury (Hg) µg/l	L0.05		
Zinc (Zn) mg/l	0.002		
Sodium (Na) mg/l	18.		
Silica (SiO_2) mg/l	0.8		
Sulphate (SO_4) mg/l	29.		
Calcium (Ca) mg/l	31.		
Hardness Total ($CaCO_3$) mg/l	128.		
Alkalinity Total ($CaCO_3$) mg/l	108.		
Specific Conductance, micromho/cm	327.		
Total Inorganic Carbon (C) mg/l	21.		
Total Organic Carbon (C) mg/l	5.		
Total Coliform (M.P.N.)	—		
Fecal Coliform (M.P.N.)	—		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 16 - NELSON RIVER @ WARREN LANDING

CONSTITUENTS	SAMPLING DATES July 22, 1974	Sept. 16, 1974	
Turbidity	2.8	3.0	
Temperature (Field) °C	18.9	11.9	
Temperature (Lab) °C	23.2	21.0	
Colour	5.	5.	
pH	7.9	8.7	
Chloride (Cl) mg/l	16.	16.	
Copper (Cu) mg/l	0.003	0.010	
Fluoride (F) mg/l	0.08	0.10	
Iron (Fe) mg/l	0.18	0.13	
Lead (Pb) mg/l	L0.004	0.010	
Manganese (Mn) mg/l	L0.01	L0.010	
Nitrogen T. Kjeldahl (N) mg/l	0.7	0.7	
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.10	
Phosphorus Total (P) mg/l	0.008	0.014	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	
Potassium (K) mg/l	2.2	2.5	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) microgram/l	0.11	0.17	
Zinc (Zn) mg/l	0.001	0.003	
Sodium (Na) mg/l	17.	19.	
Silica (SiO_2) mg/l	0.3	0.4	
Sulphate (SO_4) mg/l	28.	33.	
Calcium (Ca) mg/l	31.	35.	
Hardness Total ($CaCO_3$) mg/l	116.	130.	
Alkalinity Total ($CaCO_3$) mg/l	95.	124.	
Specific Conductance, micromho/cm	268.	351.	
Total Inorganic Carbon (C) mg/l	22.	23.	
Total Organic Carbon (C) mg/l	8.	9.	
Total Coliform (M.P.N.)	0.	3.	
Fecal Coliform (M.P.N.)	0.	0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION # OLD 17 - KISPACHEWUK RAPIDS

After April 1973 this station has been replaced by Cross Lake at Minago River

CONSTITUENTS	SAMPLING DATES July 26/72	August 29/72	September 27/72
Turbidity	25	21	23
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	23.0	22.8	—
Colour	30.	20.	20.
pH	8.1	7.4	—
Chloride (Cl) mg/l	15.4	17.4	15.3
Copper (Cu) mg/l	0.009	0.003	0.005
Fluoride (F) mg/l	0.07	0.08	0.08
Iron (Fe) mg/l	L 0.05	0.30	0.05
Lead (Pb) mg/l	L 0.002	L 0.005	L 0.00
Manganese (Mn) mg/l	—	0.005	L 0.00
Nitrogen T. Kjeldahl (N) mg/l	0.74	0.48	0.55
Nitrogen Nitrate, Nitrite (N) mg/l	0.20	0.72	0.06
Phosphorus Total (P) mg/l	0.036	0.031	0.00
Phosphorus Ortho (P) mg/l	0.012	0.004	0.00
Inorganic Phosphorus (P) mg/l	0.013	0.004	0.00
Potassium (K) mg/l	2.2	2.2	1.8
Non Filterable Residue, mg/l	9.2	9.2	27.2
Fixed Residue, mg/l	4.4	3.2	21.6
Mercury (Hg) µg/l	0.04	0.04	0.23
Zinc (Zn) mg/l	0.010	0.013	L 0.02
Sodium (Na) mg/l	14.6	15.8	15.2
Silica (SiO_2) mg/l	1.1	1.2	1.2
Sulphate (SO_4) mg/l	22.7	31.1	26.0
Calcium (Ca) mg/l	27.3	33.3	—
Hardness Total ($CaCO_3$) mg/l	104.	120.	—
Alkalinity Total ($CaCO_3$) mg/l	85.1	88.5	—
Specific Conductance, micromho/cm	262.	309.	316.
Total Inorganic Carbon (C) mg/l	14.	17.	11.
Total Organic Carbon (C) mg/l	15.	10.	8.
Total Coliform (M.P.N.)	4.	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # OLD 17 - KISPACHEWUK RAPIDS
After April 1973 this station has been replaced by Cross Lake at Minago River

CONSTITUENTS	SAMPLING DATES October 19/72	November 20/72	January 17/73
Turbidity	28.	16.	7.3
Temperature (Field)°C	—	—	0
Temperature (Lab)°C	22.2	21.3	26.
Colour	20.	20.	10.
pH	8.3	8.3	8.3
Chloride (Cl) mg/l	17.3	17.1	18.5
Copper (Cu) mg/l	L 0.002	0.002	L 0.002
Fluoride (F) mg/l	0.07	0.06	0.11
Iron (Fe) mg/l	L 0.04	0.01	L 0.01
Lead (Pb) mg/l	L 0.008	L 0.006	L 0.006
Manganese (Mn) mg/l	L 0.008	L 0.008	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.87	0.83	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.41	0.11	0.05
Phosphorus Total (P) mg/l	0.027	0.027	0.020
Phosphorus Ortho (P) mg/l	L 0.003	0.004	L 0.003
Inorganic Phosphorus (P) mg/l	0.005	0.005	0.003
Potassium (K) mg/l	2.1	2.1	2.7
Non Filterable Residue, mg/l	20.0	12.4	0.8
Fixed Residue, mg/l	12.8	10.4	L 0.1
Mercury (Hg) µg/l	0.12	0.18	0.18
Zinc (Zn) mg/l	L 0.003	0.002	0.001
Sodium (Na) mg/l	17.5	17.5	18.0
Silica (SiO_2) mg/l	0.9	0.6	0.6
Sulphate (SO_4) mg/l	30.1	31.1	32.6
Calcium (Ca) mg/l	32.2	34.4	39.5
Hardness Total ($CaCO_3$) mg/l	125.	134.	147.
Alkalinity Total ($CaCO_3$) mg/l	107.	116.	125.
Specific Conductance, micromho/cm	328.	348.	364.
Total Inorganic Carbon (C) mg/l	16.	18.	24.
Total Organic Carbon (C) mg/l	22.	13.	5.
Total Coliform (M.P.N.)	4.	9.	0.
Fecal Coliform (M.P.N.)	0.	4.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # OLD 17 - KISPACHEWUK RAPIDS
After April 1973 this station has been replaced by Cross Lake at Minago River

CONSTITUENTS	SAMPLING DATES January 24/73	February 19/73	April 3/73
Turbidity	6,5	6.0	5.4
Temperature (Field)°C	0	—	—
Temperature (Lab)°C	24.5	23.0	20.0
Colour	15.	10.	10.
pH	8.2	8.3	8.2
Chloride (Cl) mg/l	18.7	18.4	18.0
Copper (Cu) mg/l	0.002	L 0.002	L 0.003
Fluoride (F) mg/l	0.07	0.09	0.10
Iron (Fe) mg/l	L 0.01	L 0.01	L 0.01
Lead (Pb) mg/l	0.004	L 0.003	L 0.004
Manganese (Mn) mg/l	L 0.006	L 0.004	0.060
Nitrogen T. Kjeldahl (N) mg/l	0.41	—	0.36
Nitrogen Nitrate, Nitrite (N) mg/l	0.22	0.06	0.16
Phosphorus Total (P) mg/l	0.021	0.027	—
Phosphorus Ortho (P) mg/l	0.007	0.004	L 0.003
Inorganic Phosphorus (P) mg/l	0.007	0.009	0.004
Potassium (K) mg/l	2.5	2.6	2.2
Non Filterable Residue, mg/l	2.4	3.2	—
Fixed Residue, mg/l	L 0.1	L 0.1	—
Mercury (Hg) µg/l	0.03	0.11	0.03
Zinc (Zn) mg/l	0.002	L 0.002	0.003
Sodium (Na) mg/l	17.7	17.9	18.0
Silica (SiO_2) mg/l	0.6	1.2	1.0
Sulphate (SO_4) mg/l	33.9	35.7	31.2
Calcium (Ca) mg/l	38.3	43.7	43.7
Hardness Total ($CaCO_3$) mg/l	146.	142.	142.
Alkalinity Total ($CaCO_3$) mg/l	123.	121.	118.
Specific Conductance, micromho/cm	356.	354.	365.
Total Inorganic Carbon (C) mg/l	—	19.	21.
Total Organic Carbon (C) mg/l	—	6.	9.
Total Coliform (M.P.N.)	0	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml
L = Less than

STATION # 17 Nelson River at Cross Lake (Minago mouth)

CONSTITUENTS	SAMPLING DATES May 9, 1973	June 12, 1973	July 16, 1973
Turbidity	5.4	17.	15.
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	25.7	26.9	24.0
Colour	10.	20.	15.
pH	8.3	8.1	8.2
Chloride (Cl) mg/l	15.3	18.	16.
Copper (Cu) mg/l	<0.003	0.003	0.003
Fluoride (F) mg/l	0.07	0.09	0.07
Iron (Fe) mg/l	<0.04	<0.05	<0.05
Lead (Pb) mg/l	<0.002	<0.005	<0.004
Manganese (Mn) mg/l	0.019	<0.006	<0.008
Nitrogen T. Kjeldahl (N) mg/l	0.55	0.46	0.56
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.01	0.10
Phosphorus Total (P) mg/l	0.004	0.04	0.011
Phosphorus Ortho (P) mg/l	<0.003	<0.003	0.003
Inorganic Phosphorus (P) mg/l	0.003	<0.003	2.2
Potassium (K) mg/l	2.0	2.3	0.1
Non Filterable Residue, mg/l	-	-	<0.1
Fixed Residue, mg/l	-	-	<0.04
Mercury (Hg) µg/l	<0.04	<0.02	<0.001
Zinc (Zn) mg/l	<0.001	<0.002	16.
Sodium (Na) mg/l	16.3	16.	1.2
Silica (SiO_2) mg/l	0.4	0.7	36.
Sulphate (SO_4) mg/l	29.3	31.6	30.
Calcium (Ca) mg/l	32.3	33.8	119.
Hardness Total ($CaCO_3$) mg/l	123.	125.	93.
Alkalinity Total ($CaCO_3$) mg/l	106.	101.	304.
Specific Conductance, micromho/cm	325.	330.	20.
Total Inorganic Carbon (C) mg/l	8.	17.	8.
Total Organic Carbon (C) mg/l	14.	8.	23.
Total Coliform (M.P.N.)	1.5	4.	23.
Fecal Coliform (M.P.N.)	0	0	4.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 17 Nelson River at Cross Lake (Minago Mouth)

CONSTITUENTS	SAMPLING DATES Sept. 6, 1973	Oct. 17, 1973	Nov. 21, 1973
Turbidity	8.0	14.	16.
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	21.8	21.8	16.6
Colour	25.	15.	30.
pH	8.3	8.0	8.1
Chloride (Cl) mg/l	17.	16.	19.
Copper (Cu) mg/l	L0.001	0.001	0.002
Fluoride (F) mg/l	L0.08	0.07	0.12
Iron (Fe) mg/l	0.02	0.06	L 0.02
Lead (Pb) mg/l	L0.005	L0.008	L 0.008
Manganese (Mn) mg/l	L0.009	L0.010	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	-	0.7	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.04	0.04
Phosphorus Total (P) mg/l	-	0.005	0.004
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	L0.003
Potassium (K) mg/l	2.3	2.4	23.
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	L0.02	0.04	0.02
Zinc (Zn) mg/l	0.005	0.001	0.008
Sodium (Na) mg/l	17.	17.	19.
Silica (SiO_2) mg/l	2.0	2.1	1.0
Sulphate (SO_4) mg/l	28.	30.	32.
Calcium (Ca) mg/l	33.	34.	34.
Hardness Total ($CaCO_3$) mg/l	124.	132.	141.
Alkalinity Total ($CaCO_3$) mg/l	105.	112.	109.
Specific Conductance, micromho/cm	310.	335.	346.
Total Inorganic Carbon (C) mg/l	-	15.	21.
Total Organic Carbon (C) mg/l	-	9.	8.
Total Coliform (M.P.N.)	43.	15.	-
Fecal Coliform (M.P.N.)	4.	4.	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 17 Nelson River at Cross Lake (Minago Mouth)

CONSTITUENTS	SAMPLING DATES Dec. 6/73	Jnn. 29/74	Feb. 18/74
Turbidity	6.5	14.	110.
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	17.0	15.0	22.7
Colour	10.0	15.7	10.
pH	8.0	7.9	7.9
Chloride (Cl) mg/l	18.0	17.	19.
Copper (Cu) mg/l	0.003	0.002	0.004
Fluoride (F) mg/l	0.11	0.12	0.13
Iron (Fe) mg/l	L0.04	0.06	L0.04
Lead (Pb) mg/l	L0.004	L0.003	L0.003
Manganese (Mn) mg/l	L0.008	L0.02	L0.02
Nitrogen T. Kjeldahl (N) mg/l	0.6	-	0.2
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.05	0.06
Phosphorus Total (P) mg/l	L0.003	0.010	0.089
Phosphorus Ortho (P) mg/l	L0.003	0.005	0.004
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	0.006
Potassium (K) mg/l	2.2	2.5	2.5
Non Filterable Residue, mg/l	-	-	290.
Fixed Residue, mg/l	-	-	268.
Mercury (Hg) µg/l	0.11	0.03	L0.02
Zinc (Zn) mg/l	0.002	0.009	0.004
Sodium (Na) mg/l	18.	18.	19.
Silica (SiO_2) mg/l	1.1	1.0	1.3
Sulphate (SO_4) mg/l	28.	32.	32.
Calcium (Ca) mg/l	42.	46.	37.
Hardness Total ($CaCO_3$) mg/l	133.	165.	138.
Alkalinity Total ($CaCO_3$) mg/l	107.	116.	115.
Specific Conductance, micromho/cm	329.	359.	361.
Total Inorganic Carbon (C) mg/l	24.	18.	26.
Total Organic Carbon (C) mg/l	7.	7.	16.
Total Coliform (M.P.N.)	0	4.	4.
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 17 Nelson River at Cross Lake (Minago Mouth)

CONSTITUENTS	SAMPLING DATES March 25/74	April 16/74	May 20/74
Turbidity	15.	9.0	2.5
Temperature (Field)°C	--		
Temperature (Lab)°C	21.4	21.5	22.6
Colour	15.	5.	30.
pH	7.9	7.6	7.7
Chloride (Cl) mg/l	20.	16.	13.
Copper (Cu) mg/l	0.002	0.005	0.005
Fluoride (F) mg/l	0.11	0.08	0.06
Iron (Fe) mg/l	L 0.03	0.15	0.080
Lead (Pb) mg/l	0.003	0.004	L 0.004
Manganese (Mn) mg/l	L 0.010	L 0.008	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.6	1.5	0.5
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.21	0.13
Phosphorus Total (P) mg/l	0.04	0.049	0.008
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	2.6	2.4	1.8
Non Filterable Residue, mg/l	--	110.	i.s.
Fixed Residue, mg/l	--	86.	i.s.
Mercury (Hg) µg/l	L 0.05	0.03	0.10
Zinc (Zn) mg/l	L 0.001	0.003	L 0.001
Sodium (Na) mg/l	19.	16.	12.
Silica (SiO_2) mg/l	1.7	1.3	0.9
Sulphate (SO_4) mg/l	32.	31.	22.
Calcium (Ca) mg/l	35.	31.	25.
Hardness Total ($CaCO_3$) mg/l	140.	119.	95.
Alkalinity Total ($CaCO_3$) mg/l	115.	97.	81.
Specific Conductance, micromho/cm	360.	313.	243.
Total Inorganic Carbon (C) mg/l	23.	19.	18.
Total Organic Carbon (C) mg/l	8.	16.	10.
Total Coliform (M.P.N.)	0.	1100.	23.
Fecal Coliform (M.P.N.)	0.	0.	--

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s. = insufficient sample

STATION# 17 Nelson River at Cross Lake (Minago Mouth)

CONSTITUENTS	SAMPLING DATES 18/06/74	18/07/74	20/08/74
Turbidity	3.5	6.0	21.
Temperature (Field) °C			
Temperature (Lab) °C	25.1	24.5	17.6
Colour	10.	0.	10.
pH	7.9	8.0	8.4
Chloride (Cl) mg/l	20.	18.	18.
Copper (Cu) mg/l	0.001	0.001	0.005
Fluoride (F) mg/l	0.08	0.07	0.09
Iron (Fe) mg/l	L0.040	0.05	0.28
Lead (Pb) mg/l	L0.004	L0.004	0.005
Manganese (Mn) mg/l	L0.010	0.044	0.022
Nitrogen T. Kjeldahl (N) mg/l	0.6	0.4	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.07	0.03	0.05
Phosphorus Total (P) mg/l	0.13	0.01	0.018
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.003	L0.003	L0.003
Potassium (K) mg/l	2.	2.3	0.4
Non Filterable Residue, mg/l	36.	L1.0	———
Fixed Residue, mg/l	34.	L1.0	———
Mercury (Hg) µg/l	0.07	L0.05	L0.05
Zinc (Zn) mg/l	0.001	0.001	0.005
Sodium (Na) mg/l	17.	18.	18.
Silica (SiO_2) mg/l	0.7	9.	1.4
Sulphate (SO_4) mg/l	27.	29.	36.
Calcium (Ca) mg/l	30.	32.	17.
Hardness Total ($CaCO_3$) mg/l	121.	126.	68.
Alkalinity Total ($CaCO_3$) mg/l	101.	105.	117.
Specific Conductance, micromho/cm	317.	287.	341.
Total Inorganic Carbon (C) mg/l	22.	23.	17.
Total Organic Carbon (C) mg/l	9.	9.	7.
Total Coliform (M.P.N.)	0.	20.	L240.
Fecal Coliform (M.P.N.)	0.	9.	———

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 17 NELSON RIVER @ CROSS LAKE (MINAGO MOUTH)

CONSTITUENTS	SAMPLING DATES Sept. 17, 1974	Oct. 24, 1974	Nov. 20, 1974
Turbidity	23.	27.	
Temperature (Field)°C	15.	—	
Temperature (Lab)°C	21.	21.7	
Colour	10.	10.	
pH	8.5	8.1	
Chloride (Cl) mg/l	16.	19.	
Copper (Cu) mg/l	0.001	0.002	
Fluoride (F) mg/l	0.11	—	
Iron (Fe) mg/l	0.16	L0.04	
Lead (Pb) mg/l	0.01	L0.004	
Manganese (Mn) mg/l	L0.01	L0.01	
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.6	
Nitrogen Nitrate, Nitrite (N) mg/l	L0.01	0.02	
Phosphorus Total (P) mg/l	0.067	0.032	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.003	L0.003	
Potassium (K) mg/l	2.5	2.3	
Non Filterable Residue, mg/l	13.	--	
Fixed Residue, mg/l	5.	--	
Mercury (Hg) micrograms/l	L0.05	0.13	
Zinc (Zn) mg/l	0.001	L0.001	
Sodium (Na) mg/l	19.	19.	
Silica (SiO_2) mg/l	0.4	0.3	
Sulphate (SO_4) mg/l	32.	31.	
Calcium (Ca) mg/l	35.	36.	
Hardness Total ($CaCO_3$) mg/l	135.	134.	
Alkalinity Total ($CaCO_3$) mg/l	121.	114.	
Specific Conductance, micromho/cm	351.	312.	
Total Inorganic Carbon (C) mg/l	22.	22.	
Total Organic Carbon (C) mg/l	8.	8.	
Total Coliform (M.P.N.)	0.	0.	4.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 17 NELSON RIVER @ CROSS LAKE (MINAGO MOUTH)

CONSTITUENTS	SAMPLING DATES Dec. 18, 1974		
Turbidity			
Temperature (Field)°C			
Temperature (Lab)°C			
Colour			
pH			
Chloride (Cl) mg/l			
Copper (Cu) mg/l			
Fluoride (F) mg/l			
Iron (Fe) mg/l			
Lead (Pb) mg/l			
Manganese (Mn) mg/l			
Nitrogen T. Kjeldahl (N) mg/l			
Nitrogen Nitrate, Nitrite (N) mg/l			
Phosphorus Total (P) mg/l			
Phosphorus Ortho (P) mg/l			
Inorganic Phosphorus (P) mg/l			
Potassium (K) mg/l			
Non Filterable Residue, mg/l			
Fixed Residue, mg/l			
Mercury (Hg) micrograms/l			
Zinc (Zn) mg/l			
Sodium (Na) mg/l			
Silica (SiO_2) mg/l			
Sulphate (SO_4) mg/l			
Calcium (Ca) mg/l			
Hardness Total ($CaCO_3$) mg/l			
Alkalinity Total ($CaCO_3$) mg/l			
Specific Conductance, micromho/cm			
Total Inorganic Carbon (C) mg/l			
Total Organic Carbon (C) mg/l			
Total Coliform (M.P.N.)	23.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # OLD 18 - NELSON RIVER @ EVE FALLS
After April 1973 this station has been replaced with Bladder Rapids

CONSTITUENTS	SAMPLING DATES July 26/72	August 24/72	September [illegible]/72
Turbidity	34.	21.	28.
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	23.0	23.8	23.2
Colour	40.	20.	20.
pH	7.9	8.2	8.0
Chloride (Cl) mg/l	15.4	18.2	16.5
Copper (Cu) mg/l	0.002	0.005	0.003
Fluoride (F) mg/l	0.08	0.09	0.09
Iron (Fe) mg/l	L 0.05	0.44	0.06
Lead (Pb) mg/l	L 0.006	L 0.006	L 0.006
Manganese (Mn) mg/l	L 0.005	L 0.020	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.89	0.64	0.49
Nitrogen Nitrate, Nitrite (N) mg/l	0.21	0.58	0.13
Phosphorus Total (P) mg/l	0.046	0.029	0.028
Phosphorus Ortho (P) mg/l	0.003	0.005	L 0.003
Inorganic Phosphorus (P) mg/l	0.003	0.006	0.004
Potassium (K) mg/l	2.2	2.2	2.3
Non Filterable Residue, mg/l	25.2	--	27.
Fixed Residue, mg/l	18.0	—	20.
Mercury (Hg) µg/l	0.04	0.15	0.05
Zinc (Zn) mg/l	L 0.001	0.018	0.002
Sodium (Na) mg/l	14.4	15.8	16.
Silica (SiO_2) mg/l	2.1	1.1	1.0
Sulphate (SO_4) mg/l	23.0	31.1	33.3
Calcium (Ca) mg/l	25.9	30.0	30.6
Hardness Total ($CaCO_3$) mg/l	102.	113.	122.
Alkalinity Total ($CaCO_3$) mg/l	84.1	80.9	107.
Specific Conductance, micromho/cm	282.	300.	319.
Total Inorganic Carbon (C) mg/l	15.	13.	18.
Total Organic Carbon (C) mg/l	15.	10.	12.
Total Coliform (M.P.N.)	4.	43.	15.
Fecal Coliform (M.P.N.)	0	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #OLD 18 - NELSON RIVER @ EVE FALLS
(After April 1973 this station has been replaced with BLADDER RAPIDS)

CONSTITUENTS	SAMPLING DATES October 19/72	November 20/72	December 11/72
Turbidity	36.		19.
Temperature (Field)°C	—		—
Temperature (Lab)°C	23.8		23.
Colour	20.		30.
pH	8.3		8.3
Chloride (Cl) mg/l	16.2		18.2
Copper (Cu) mg/l	0.006		0.003
Fluoride (F) mg/l	0.07		0.07
Iron (Fe) mg/l	L 0.04		L 0.01
Lead (Pb) mg/l	L 0.008		L 0.006
Manganese (Mn) mg/l	L 0.008		L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.78		0.54
Nitrogen Nitrate, Nitrite (N) mg/l	0.96	NO SAMPLE SUBMITTED	L 0.01
Phosphorus Total (P) mg/l	0.037		0.033
Phosphorus Ortho (P) mg/l	L 0.003		0.003
Inorganic Phosphorus (P) mg/l	L 0.003		0.003
Potassium (K) mg/l	2.1		2.4
Non Filterable Residue, mg/l	26.		8.8
Fixed Residue, mg/l	17.2		6.4
Mercury (Hg) µg/l	1.1*		0.10
Zinc (Zn) mg/l	L 0.003		0.001
Sodium (Na) mg/l	17.5		17.6
Silica (SiO_2) mg/l	0.7		0.9
Sulphate (SO_4) mg/l	30.1		33.2
Calcium (Ca) mg/l	33.4		34.5
Hardness Total ($CaCO_3$) mg/l	135.		138.
Alkalinity Total ($CaCO_3$) mg/l	109.		117.
Specific Conductance, micromho/cm	329.		359.
Total Inorganic Carbon (C) mg/l	18.		—
Total Organic Carbon (C) mg/l	15.		—
Total Coliform (M.P.N.)	23	43	—
Fecal Coliform (M.P.N.)	0	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # OLD 18 - NELSON RIVER @ EVE FALLS
(After April 1973 this data has been replaced with BLADDER RAPIDS)

CONSTITUENTS	SAMPLING DATES January 11/73	January 24/73	February 19/73
Turbidity	8.1	7.2	7.1
Temperature (Field) °C	32.	32.	—
Temperature (Lab) °C	26.	24.5	23.0
Colour	10.	20.	20.
pH	7.9	8.1	8.1
Chloride (Cl) mg/l	18.7	18.8	19.8
Copper (Cu) mg/l	L0.002	0.002	0.002
Fluoride (F) mg/l	0.11	0.08	0.10
Iron (Fe) mg/l	L 0.01	L 0.01	L 0.01
Lead (Pb) mg/l	L 0.006	L 0.004	L 0.003
Manganese (Mn) mg/l	L 0.006	L 0.006	0.008
Nitrogen T. Kjeldahl (N) mg/l	—	0.41	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.35	0.06	0.06
Phosphorus Total (P) mg/l	0.019	0.023	0.021
Phosphorus Ortho (P) mg/l	0.003	0.008	0.003
Inorganic Phosphorus (P) mg/l	0.008	0.008	0.005
Potassium (K) mg/l	2.7	2.5	2.8
Non Filterable Residue, mg/l	L 0.1	1.2	3.2
Fixed Residue, mg/l	L 0.1	0.8	L 0.1
Mercury (Hg) µg/l	0.40	0.24	0.10
Zinc (Zn) mg/l	0.001	0.002	0.002
Sodium (Na) mg/l	17.9	17.6	18.6
Silica (SiO_2) mg/l	0.8	0.8	0.9
Sulphate (SO_4) mg/l	34.	34.5	34.1
Calcium (Ca) mg/l	38.	34.2	47.8
Hardness Total ($CaCO_3$) mg/l	146.	138.	146.
Alkalinity Total ($CaCO_3$) mg/l	121.	118.	120.
Specific Conductance, micromho/cm	357.	348.	361.
Total Inorganic Carbon (C) mg/l	23.	21.	21.
Total Organic Carbon (C) mg/l	4.	7.	8.
Total Coliform (M.P.N.)	4.	—	15.
Fecal Coliform (M.P.N.)	0	—	0

LEGEND MPN = Most probable number per 100 ml
L = Less than

STATION # OLD 18 - NELSON RIVER @ EVE FALLS
(After April 1973 this data has been replaced with BLADDER RAPIDS)

CONSTITUENTS	SAMPLING DATES April 3/73		
Turbidity	8.8		
Temperature (Field) °C	—		
Temperature (Lab) °C	22.0		
Colour	25.		
pH	8.3		
Chloride (Cl) mg/l	18.0		
Copper (Cu) mg/l	L 0.003		
Fluoride (F) mg/l	0.11		
Iron (Fe) mg/l	L 0.01		
Lead (Pb) mg/l	L 0.004		
Manganese (Mn) mg/l	L 0.008		
Nitrogen T. Kjeldahl (N) mg/l	0.46		
Nitrogen Nitrate, Nitrite (N) mg/l	0.15		
Phosphorus Total (P) mg/l	—		
Phosphorus Ortho (P) mg/l	L 0.003		
Inorganic Phosphorus (P) mg/l	L 0.003		
Potassium (K) mg/l	2.6		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	L 0.03		
Zinc (Zn) mg/l	0.011		
Sodium (Na) mg/l	18.4		
Silica (SiO_2) mg/l	1.0		
Sulphate (SO_4) mg/l	30.1		
Calcium (Ca) mg/l	44.5		
Hardness Total ($CaCO_3$) mg/l	139.		
Alkalinity Total ($CaCO_3$) mg/l	115.		
Specific Conductance, micromho/cm	355.		
Total Inorganic Carbon (C) mg/l	23.		
Total Organic Carbon (C) mg/l	7.		
Total Coliform (M.P.N.)	43.		
Fecal Coliform (M.P.N.)	4.		

LEGEND MPN = Most probable number per 100 ml
L = Less than

STATION # 18 Nelson River at Bladder Rapids

CONSTITUENTS	SAMPLING DATES May 24, 1973	June 12, 1973	Sept. 12, 1973
Turbidity	7.9	16.	15.
Temperature (Field) °C	-	12.8	-
Temperature (Lab) °C	25.0	28.0	23.3
Colour	7.	10.	20.
pH	8.3	8.2	8.1
Chloride (Cl) mg/l	15.7	16.	17.
Copper (Cu) mg/l	0.004	0.002	0.001
Fluoride (F) mg/l	0.08	0.09	-
Iron (Fe) mg/l	L0.03	L0.03	0.02
Lead (Pb) mg/l	0.010	L0.005	L0.005
Manganese (Mn) mg/l	L0.007	L0.006	L0.009
Nitrogen T. Kjeldahl (N) mg/l	0.62	0.52	-
Nitrogen Nitrate, Nitrite (N) mg/l	0.05	0.01	26.
Phosphorus Total (P) mg/l	-	0.021	0.12
Phosphorus Ortho (P) mg/l	-	0.003	0.006
Inorganic Phosphorus (P) mg/l	-	0.004	0.008
Potassium (K) mg/l	2.3	2.2	2.2
Non Filterable Residue, mg/l	14.4	5.5	-
Fixed Residue, mg/l	11.2	1.5	-
Mercury (Hg) µg/l	-	-	L0.05
Zinc (Zn) mg/l	0.005	L0.002	0.003
Sodium (Na) mg/l	16.8	15.	15.
Silica (SiO_2) mg/l	0.4	0.9	-
Sulphate (SO_4) mg/l	32.7	29.	35.
Calcium (Ca) mg/l	34.0	31.1	36.
Hardness Total ($CaCO_3$) mg/l	120.	120.	124.
Alkalinity Total ($CaCO_3$) mg/l	103.	100.	104.
Specific Conductance, micromho/cm	316.	324.	308.
Total Inorganic Carbon (C) mg/l	21.	19.	19.
Total Organic Carbon (C) mg/l	5.	7.	7.
Total Coliform (M.P.N.)			
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES July 12/72	August 2/72	Sept. 6/72
Turbidity	21	20	32
Temperature (Field) °C	18.5	-	-
Temperature (Lab) °C	24	-	25.5
Colour	70	60	50
pH	8.0	7.9	7.6
Chloride (Cl) mg/l	0.9	0.6	1.8
Copper (Cu) mg/l	0.002	L0.001	0.003
Fluoride (F) mg/l	0.06	0.08	0.07
Iron (Fe) mg/l	0.04	0.08	0.18
Lead (Pb) mg/l	L0.004	L0.002	L0.006
Manganese (Mn) mg/l	L0.010	L0.008	0.012
Nitrogen T. Kjeldahl (N) mg/l	0.75	0.95	1.14
Nitrogen Nitrate, Nitrite (N) mg/l	0.16	0.09	0.84
Phosphorus Total (P) mg/l	0.036	0.035	-
Phosphorus Ortho (P) mg/l	0.007	L0.003	0.056
Inorganic Phosphorus (P) mg/l	0.01	0.004	0.057
Potassium (K) mg/l	0.9	0.7	1.0
Non Filterable Residue, mg/l	9.6	5.5	11.6
Fixed Residue, mg/l	4.4	L0.1	9.2
Mercury (Hg) µg/l	0.27	0.16	0.69
Zinc (Zn) mg/l	0.001	0.002	0.16
Sodium (Na) mg/l	2.5	2.2	3.0
Silica (SiO_2) mg/l	3.0	3.7	3.7
Sulphate (SO_4) mg/l	2.4	1.62	5.2
Calcium (Ca) mg/l	19.0	16.5	17.5
Hardness Total ($CaCO_3$) mg/l	61.3	58.8	63.6
Alkalinity Total ($CaCO_3$) mg/l	55.8	53.1	58.4
Specific Conductance, micromho/cm	120	114	131
Total Inorganic Carbon (C) mg/l	7	7	7
Total Organic Carbon (C) mg/l	14	14	18
Total Coliform (M.P.N.)	4	9	23
Fecal Coliform (M.P.N.)	-	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = sample contaminated

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES		
	Oct. 4/72	Nov. 7/72	Dec. 6/72
Turbidity	27	15	8.0
Temperature (Field) °C	-	0	-
Temperature (Lab) °C	21.1	22	22
Colour	40	50	55
pH	8.1	8.0	7.8
Chloride (Cl) mg/l	0.8	0.8	1.0
Copper (Cu) mg/l	0.004	0.006	0.002
Fluoride (F) mg/l	0.06	0.07	L0.05
Iron (Fe) mg/l	0.08	0.05	0.08
Lead (Pb) mg/l	L0.010	0.006	L0.006
Manganese (Mn) mg/l	L0.006	L0.010	L0.005
Nitrogen T. Kjeldahl (N) mg/l	0.87	1.23	0.68
Nitrogen Nitrate, Nitrite (N) mg/l	0.27	26	0.03
Phosphorus Total (P) mg/l	0.053	0.028	0.033
Phosphorus Ortho (P) mg/l	0.003	0.007	0.007
Inorganic Phosphorus (P) mg/l	0.005	0.007	0.009
Potassium (K) mg/l	0.8	0.9	1.0
Non Filterable Residue, mg/l	10.8	4.8	3.6
Fixed Residue, mg/l	8.0	4.4	0.8
Mercury (Hg) µg/l	L0.05	0.36	0.17
Zinc (Zn) mg/l	0.002	0.030	L0.001
Sodium (Na) mg/l	2.7	2.3	2.4
Silica (SiO_2) mg/l	3.0	3.8	3.7
Sulphate (SO_4) mg/l	7.1	2.9	5.7
Calcium (Ca) mg/l	19.2	18.0	18.7
Hardness Total ($CaCO_3$) mg/l	63.8	63.4	66.1
Alkalinity Total ($CaCO_3$) mg/l	59.9	59.2	58.4
Specific Conductance, micromho/cm	123	125	137
Total Inorganic Carbon (C) mg/l	11	13	14
Total Organic Carbon (C) mg/l	10	13	13
Total Coliform (M.P.N.)	9	0	4
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES Jan. 8/73	Feb. 7/73	March 1/73
Turbidity	10	8.0	8.2
Temperature (Field) °C	0	0	0
Temperature (Lab) °C	26	25	23.0
Colour	40	50	40
pH	7.5	7.8	8.0
Chloride (Cl) mg/l	1.0	1.0	1.1
Copper (Cu) mg/l	0.003	L0.002	0.002
Fluoride (F) mg/l	0.07	0.05	0.07
Iron (Fe) mg/l	0.08	0.09	0.09
Lead (Pb) mg/l	0.006	L0.003	-
Manganese (Mn) mg/l	L0.006	0.004	L0.008
Nitrogen T. Kjeldahl (N) mg/l	0.91	0.71	0.39
Nitrogen Nitrate, Nitrite (N) mg/l	0.51	0.22	0.14
Phosphorus Total (P) mg/l	0.025	0.027	0.028
Phosphorus Ortho (P) mg/l	0.007	0.010	0.009
Inorganic Phosphorus (P) mg/l	0.010	0.013	0.010
Potassium (K) mg/l	1.0	0.9	1.0
Non Filterable Residue, mg/l	9.6	6.4	-
Fixed Residue, mg/l	4.0	1.6	-
Mercury (Hg) µg/l	0.38	0.13	0.04
Zinc (Zn) mg/l	0.002	L0.002	0.046
Sodium (Na) mg/l	2.6	2.5	2.7
Silica (SiO_2) mg/l	3.8	4.6	4.2
Sulphate (SO_4) mg/l	2.6	6.2	3.6
Calcium (Ca) mg/l	18.7	19.6	22.0
Hardness Total ($CaCO_3$) mg/l	68.7	72.6	72.9
Alkalinity Total ($CaCO_3$) mg/l	62.6	65.8	69.6
Specific Conductance, micromho/cm	172	140	138
Total Inorganic Carbon (C) mg/l	14	13	15
Total Organic Carbon (C) mg/l	14	13	12
Total Coliform (M.P.N.)	4	0	4
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES		
	April 4/73	May 2/73	June 20/73
Turbidity	6.8	9.4	24
Temperature (Field) °C	1.0	-	14
Temperature (Lab) °C	25.0	23.0	25
Colour	40	45	50
pH	8.0	8.2	8.1
Chloride (Cl) mg/l	1.5	2.5	1.0
Copper (Cu) mg/l	L0.003	0.004	0.002
Fluoride (F) mg/l	0.07	0.07	0.07
Iron (Fe) mg/l	0.10	0.10	0.12
Lead (Pb) mg/l	L0.004	0.004	L0.002
Manganese (Mn) mg/l	L0.008	L0.008	L0.[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.64	1.46	1.[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	[illegible]	0.15	0.[illegible]
Phosphorus Total (P) mg/l	[illegible]	0.025	0.[illegible]
Phosphorus Ortho (P) mg/l	0.006	L0.003	L0.002
Inorganic Phosphorus (P) mg/l	0.010	0.007	0.[illegible]
Potassium (K) mg/l	1.1	1.0	1.2
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	0.03	0.02	L0.02
Zinc (Zn) mg/l	L0.002	-	L0.002
Sodium (Na) mg/l	2.3	2.8	2.[illegible]
Silica (SiO_2) mg/l	4.5	4.5	2.8
Sulphate (SO_4) mg/l	2.1	3.8	4.7
Calcium (Ca) mg/l	21.9	23.1	18.[illegible]
Hardness Total ($CaCO_3$) mg/l	75.4	76.8	50.[illegible]
Alkalinity Total ($CaCO_3$) mg/l	70.6	73.1	53.8
Specific Conductance, micromho/cm	157	156	117.
Total Inorganic Carbon (C) mg/l	14	13	10.
Total Organic Carbon (C) mg/l	14	13	11.
Total Coliform (M.P.N.)	4	43	0.
Fecal Coliform (M.P.N.)	0	0	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES July 3/73	Aug. 1/73	Sept. 6/73
Turbidity		25	
Temperature (Field) °C		-	
Temperature (Lab) °C		25.5	
Colour		50	
pH		7.6	
Chloride (Cl) mg/l		2.1	
Copper (Cu) mg/l		0.003	
Fluoride (F) mg/l		L0.05	
Iron (Fe) mg/l		0.15	
Lead (Pb) mg/l		0.006	
Manganese (Mn) mg/l		L0.008	
Nitrogen T. Kjeldahl (N) mg/l		0.9	
Nitrogen Nitrate, Nitrite (N) mg/l		0.07	
Phosphorus Total (P) mg/l		0.038	
Phosphorus Ortho (P) mg/l		0.011	
Inorganic Phosphorus (P) mg/l		0.012	
Potassium (K) mg/l		1.2	
Non Filterable Residue, mg/l		3.5	
Fixed Residue, mg/l		L0.1	
Mercury (Hg) µg/l		0.14	
Zinc (Zn) mg/l		0.002	
Sodium (Na) mg/l		3.0	
Silica (SiO_2) mg/l		3.1	
Sulphate (SO_4) mg/l		7.5	
Calcium (Ca) mg/l		20	
Hardness Total ($CaCO_3$) mg/l		65	
Alkalinity Total ($CaCO_3$) mg/l		62	
Specific Conductance, micromho/cm		139	
Total Inorganic Carbon (C) mg/l		12	
Total Organic Carbon (C) mg/l		12	
Total Coliform (M.P.N.)	L240	4	140
Fecal Coliform (M.P.N.)	-	-	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES Nov. 7/73	Dec. 6/73	Feb. 7/74
Turbidity	25	11	8.1
Temperature (Field) °C	2.2	-	0.5
Temperature (Lab) °C	16.7	17.1	17.6
Colour	60	45	45
pH	7.7	7.7	7.4
Chloride (Cl) mg/l	1.1	1.3	1.4
Copper (Cu) mg/l	0.003	0.001	0.003
Fluoride (F) mg/l	0.08	0.07	0.06
Iron (Fe) mg/l	0.06	0.07	0.23
Lead (Pb) mg/l	L0.008	-	L0.003
Manganese (Mn) mg/l	L0.009	L0.002	L0.02
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.7	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.03	0.10
Phosphorus Total (P) mg/l	0.026	0.020	0.022
Phosphorus Ortho (P) mg/l	0.003	0.006	0.012
Inorganic Phosphorus (P) mg/l	0.007	0.008	-
Potassium (K) mg/l	0.7	0.9	1.0
Non Filterable Residue, mg/l	7.2	-	-
Fixed Residue, mg/l	2.0	-	-
Mercury (Hg) µg/l	0.04	0.05	0.13
Zinc (Zn) mg/l	L0.004	0.005	L0.002
Sodium (Na) mg/l	3.0	2.8	2.6
Silica (SiO_2) mg/l	2.3	3.2	4.2
Sulphate (SO_4) mg/l	4.1	3.4	3.6
Calcium (Ca) mg/l	42	22	24
Hardness Total ($CaCO_3$) mg/l	119	82	77
Alkalinity Total ($CaCO_3$) mg/l	80	73	74
Specific Conductance, micromho/cm	144	142	153
Total Inorganic Carbon (C) mg/l	12	16	14
Total Organic Carbon (C) mg/l	15	11	11
Total Coliform (M.P.N.)	0	4	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

ATION# 19 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES March 6/74	April 4/74	May 2/74
Turbidity	12.	8.5	22.
Temperature (Field) °C	4.	--	0.
Temperature (Lab) °C	19.1	20.1	22.1
Colour	45.	35.	65.
pH	7.6	7.7	7.5
Chloride (Cl) mg/l	1.2	1.3	11.4
Copper (Cu) mg/l	0.023	0.004	0.004
Fluoride (F) mg/l	L 0.05	0.06	L 0.05
Iron (Fe) mg/l	0.33	0.07	0.15
Lead (Pb) mg/l	0.003	0.007	0.006
Manganese (Mn) mg/l	0.012	0.011	L 0.010
Nitrogen T. Kjeldahl (N) mg/l	0.3	0.5	0.9
Nitrogen Nitrate, Nitrite (N) mg/l	0.37	0.13	0.11
Phosphorus Total (P) mg/l	0.015	0.022	--
Phosphorus Ortho (P) mg/l	0.007	0.009	0.013
Inorganic Phosphorus (P) mg/l	0.010	0.010	0.016
Potassium (K) mg/l	1.0	1.0	1.0
Non Filterable Residue, mg/l	--	i.s.	--
Fixed Residue, mg/l	--	--	--
Mercury (Hg) µg/l	0.22	1.2	0.04
Zinc (Zn) mg/l	0.001	0.006	0.001
Sodium (Na) mg/l	3.0	3.0	2.0
Silica (SiO_2) mg/l	4.8	4.8	4.4
Sulphate (SO_4) mg/l	4.3	3.5	3.9
Calcium (Ca) mg/l	23.	23.	20.
Hardness Total ($CaCO_3$) mg/l	81.	81.	65.
Alkalinity Total ($CaCO_3$) mg/l	76.	79.	60.
Specific Conductance, micromho/cm	155.	168.	128.
Total Inorganic Carbon (C) mg/l	17.	18.	12.
Total Organic Carbon (C) mg/l	13.	12.	15.
Total Coliform (M.P.N.)	0.		15.
Fecal Coliform (M.P.N.)	0.		0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION#9 Burntwood River at Thompson

CONSTITUENTS	SAMPLING DATES June 3/74	July 4/74	August 1/74
Turbidity	19.	31.	28.
Temperature (Field) °C	22.	——	12.
Temperature (Lab) °C	22.2	21.1	22.5
Colour	70.	60.	50.
pH	7.7	7.2	7.9
Chloride (Cl) mg/l	1.3	0.8	1.5
Copper (Cu) mg/l	0.002	0.003	0.003
Fluoride (F) mg/l	L0.05	0.06	0.07
Iron (Fe) mg/l	0.12	0.003	0.10
Lead (Pb) mg/l	0.009	L0.004	L0.004
Manganese (Mn) mg/l	L0.010	0.11	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.5	0.8
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.04	0.03
Phosphorus Total (P) mg/l	0.040	0.041	0.040
Phosphorus Ortho (P) mg/l	0.003	0.01	L0.003
Inorganic Phosphorus (P) mg/l	0.006	0.013	L0.003
Potassium (K) mg/l	1.2	1.2	0.9
Non Filterable Residue, mg/l	——	——	i.s.
Fixed Residue, mg/l	——	——	i.s.
Mercury (Hg) µg/l	0.11	L0.05	0.22
Zinc (Zn) mg/l	0.004	0.001	0.005
Sodium (Na) mg/l	2.1	2.6	2.5
Silica (SiO_2) mg/l	3.4	3.2	4.4
Sulphate (SO_4) mg/l	4.2	4.1	5.0
Calcium (Ca) mg/l	19.	19.	20.
Hardness Total ($CaCO_3$) mg/l	57.	63.	70.
Alkalinity Total ($CaCO_3$) mg/l	52.	59.	67.
Specific Conductance, micromho/cm	114.	120.	130.
Total Inorganic Carbon (C) mg/l	12.	13.	15.
Total Organic Carbon (C) mg/l	14.	23.	12.
Total Coliform (M.P.N.)	9.	4.	390.
Fecal Coliform (M.P.N.)	4.		0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s.= Insufficient Sample

STATION# 19 BURNTWOOD RIVER AT THOMPSON

CONSTITUENTS	SAMPLING DATES Sept. 3, 1974	Oct. 4, 1974	Nov. 5, 1974
Turbidity	32.	40.	20.
Temperature (Field)°C	11.5	4.	3.8
Temperature (Lab)°C	22.9	18.3	21.5
Colour	40.	40.	45.
pH	8.0	8.0	7.7
Chloride (Cl) mg/l	0.9	0.8	1.0
Copper (Cu) mg/l	0.008	0.003	0.007
Fluoride (F) mg/l	0.06	L0.05	0.1
Iron (Fe) mg/l	0.15	0.06	0.07
Lead (Pb) mg/l	0.005	0.004	L0.004
Manganese (Mn) mg/l	0.026	L0.010	L0.01
Nitrogen T. Kjeldahl (N) mg/l	L0.1	0.6	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	0.04	0.03
Phosphorus Total (P) mg/l	0.030	0.038	0.02
Phosphorus Ortho (P) mg/l	L0.003	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.003	0.003	0.003
Potassium (K) mg/l	0.9	0.9	0.9
Non Filterable Residue, mg/l	1.	27.	—
Fixed Residue, mg/l	L1.	19.5	—
Mercury (Hg) µg/l	0.08	0.07	—
Zinc (Zn) mg/l	0.003	0.002	0.002
Sodium (Na) mg/l	2.3	2.7	2.7
Silica (SiO_2) mg/l	4.6	3.4	2.4
Sulphate (SO_4) mg/l	3.1	3.9	3.8
Calcium (Ca) mg/l	21.	22.	21.
Hardness Total ($CaCO_3$) mg/l	73.	79.	77.
Alkalinity Total ($CaCO_3$) mg/l	71.	73.	73.
Specific Conductance, micromho/cm	144.	153.	148.
Total Inorganic Carbon (C) mg/l	15.	17.	16.
Total Organic Carbon (C) mg/l	13.	12.	11.
Total Coliform (M.P.N.)	15.	4.	
Fecal Coliform (M.P.N.)	0.	0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES July 11/72	August 21/72	September 19/72
Turbidity	20.	29.	8.9
Temperature (Field) °C	19.5	21.1	—
Temperature (Lab) °C	23.8	23.0	23.0
Colour	70	70	60
pH	8.0	8.0	8.0
Chloride (Cl) mg/l	0.7	0.2	0.9
Copper (Cu) mg/l	0.001	—	—
Fluoride (F) mg/l	0.05	—	—
Iron (Fe) mg/l	0.06	—	—
Lead (Pb) mg/l	L 0.004	—	—
Manganese (Mn) mg/l	L 0.010	—	—
Nitrogen T. Kjeldahl (N) mg/l	0.79	—	0.03
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.10	—
Phosphorus Total (P) mg/l	—	—	—
Phosphorus Ortho (P) mg/l	L 0.003	—	—
Inorganic Phosphorus (P) mg/l	0.008	—	—
Potassium (K) mg/l	0.5	0.5	0.6
Non Filterable Residue, mg/l	13.2	—	—
Fixed Residue, mg/l	7.2	—	—
Mercury (Hg) µg/l	0.15	L 0.04	1.9*
Zinc (Zn) mg/l	L 0.001	—	—
Sodium (Na) mg/l	2.2	2.2	2.9
Silica (SiO_2) mg/l	1.4	2.4	3.2
Sulphate (SO_4) mg/l	1.5	1.8	3.1
Calcium (Ca) mg/l	17.8	18.3	23.4
Hardness Total ($CaCO_3$) mg/l	60.6	66.1	81.3
Alkalinity Total ($CaCO_3$) mg/l	56.2	63.5	78.7
Specific Conductance, micromho/cm	115.	140.	159.
Total Inorganic Carbon (C) mg/l	7.	—	—
Total Organic Carbon (C) mg/l	20.	—	—
Total Coliform (M.P.N.)	43	43	43
Fecal Coliform (M.P.N.)	—	9	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

* Like acid contaminated, disregard this value

STATION #20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES October 20/72	December 13/72	February 14/73
Turbidity	4.4	6.0	6.4
Temperature (Field) °C	—	0	0
Temperature (Lab) °C	22.8	22.6	23.2
Colour	40	70	120
pH	7.9	8.4	8.0
Chloride (Cl) mg/l	1.4	1.4	2.3
Copper (Cu) mg/l	0.002	0.002	L 0.002
Fluoride (F) mg/l	L 0.05	L 0.05	0.07
Iron (Fe) mg/l	0.06	0.29	0.92
Lead (Pb) mg/l	L 0.008	0.005	L 0.003
Manganese (Mn) mg/l	L 0.006	0.29	0.065
Nitrogen T. Kjeldahl (N) mg/l	1.12	1.17	1.7
Nitrogen Nitrate, Nitrite (N) mg/l	—	0.11	0.06
Phosphorus Total (P) mg/l	0.014	0.25	0.004
Phosphorus Ortho (P) mg/l	0.006	0.004	0.003
Inorganic Phosphorus (P) mg/l	0.006	0.005	0.004
Potassium (K) mg/l	0.5	1.2	1.5
Non Filterable Residue, mg/l	3.6	—	—
Fixed Residue, mg/l	0.8	—	—
Mercury (Hg) µg/l	0.14	0.26	0.06
Zinc (Zn) mg/l	L 0.003	L 0.001	0.002
Sodium (Na) mg/l	3.5	3.7	3.8
Silica (SiO_2) mg/l	3.0	5.0	6.9
Sulphate (SO_4) mg/l	—	2.7	2.3
Calcium (Ca) mg/l	19.2	29.8	35.6
Hardness Total ($CaCO_3$) mg/l	68.9	101.	123.
Alkalinity Total ($CaCO_3$) mg/l	63.3	95.4	116.
Specific Conductance, micromho/cm	144.	198.	233.
Total Inorganic Carbon (C) mg/l	13.	20.	26.
Total Organic Carbon (C) mg/l	17.	23.	21.
Total Coliform (M.P.N.)	43	43	23
Fecal Coliform (M.P.N.)	0	4	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES March 20/73	April 25/73	May 7/73
Turbidity	7.2	8.1	74.
Temperature (Field) °C	0	—	—
Temperature (Lab) °C	23.0	24.5	27.0
Colour	100.	90.	60.
pH	7.8	8.1	8.1
Chloride (Cl) mg/l	1.8	2.2	1.0
Copper (Cu) mg/l	L 0.003	L 0.001	L 0.003
Fluoride (F) mg/l	0.08	0.07	L 0.05
Iron (Fe) mg/l	1.11	0.67	0.31
Lead (Pb) mg/l	—	L 0.003	L 0.002
Manganese (Mn) mg/l	0.040	0.016	0.008
Nitrogen T. Kjeldahl (N) mg/l	—	0.85	0.70
Nitrogen Nitrate, Nitrite (N) mg/l	0.12	0.04	0.13
Phosphorus Total (P) mg/l	0.037	0.04	0.072
Phosphorus Ortho (P) mg/l	0.004	0.005	L 0.003
Inorganic Phosphorus (P) mg/l	0.008	0.008	L 0.003
Potassium (K) mg/l	1.6	1.6	1.0
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.04	2.7	L 0.04
Zinc (Zn) mg/l	L 0.002	0.003	L 0.001
Sodium (Na) mg/l	4.8	3.6	1.8
Silica (SiO_2) mg/l	7.2	7.6	3.6
Sulphate (SO_4) mg/l	3.2	13.3	3.9
Calcium (Ca) mg/l	40.3	32.6	19.4
Hardness Total ($CaCO_3$) mg/l	133.	113.	61.8
Alkalinity Total ($CaCO_3$) mg/l	130.	99.4	59.0
Specific Conductance, micromho/cm	268	232	120
Total Inorganic Carbon (C) mg/l	23	25	12
Total Organic Carbon (C) mg/l	23	19	17
Total Coliform (M.P.N.)	23	43	93
Fecal Coliform (M.P.N.)	4	0	9

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Likely acid contaminated disregard this value

STATION # 20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES June 22/73	August 8/73	September 10/73
Turbidity	12	10	8.5
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	26.0	25.8	20.3
Colour	30.	80.	70.
pH	7.8	7.5	7.6
Chloride (Cl) mg/l	1.1	1.5	1.2
Copper (Cu) mg/l	0.002	L 0.002	L 0.001
Fluoride (F) mg/l	0.07	L 0.05	0.07
Iron (Fe) mg/l	0.07	0.11	0.05
Lead (Pb) mg/l	L 0.005	L 0.004	L 0.005
Manganese (Mn) mg/l	L 0.006	L 0.009	L 0.009
Nitrogen T. Kjeldahl (N) mg/l	—	0.7	—
Nitrogen Nitrate, Nitrite (N) mg/l	0.03	0.11	0.03
Phosphorus Total (P) mg/l	0.021	0.012	—
Phosphorus Ortho (P) mg/l	L 0.003	0.003	—
Inorganic Phosphorus (P) mg/l	L 0.003	0.003	—
Potassium (K) mg/l	0.7	0.5	0.6
Non Filterable Residue, mg/l	1.0	—	12.
Fixed Residue, mg/l	3.2	—	8.0
Mercury (Hg) µg/l	0.02	L 0.03	L 0.02
Zinc (Zn) mg/l	L 0.002	L 0.001	0.001
Sodium (Na) mg/l	2.9	2.8	2.8
Silica (SiO_2) mg/l	1.0	5.1	4.4
Sulphate (SO_4) mg/l	3.8	3.6	4.0
Calcium (Ca) mg/l	17.2	26.	21.
Hardness Total ($CaCO_3$) mg/l	61.8	77.	73.
Alkalinity Total ($CaCO_3$) mg/l	57.1	69.	70.
Specific Conductance, micromho/cm	122.	133.	140.
Total Inorganic Carbon (C) mg/l	13.	15.	15.
Total Organic Carbon (C) mg/l	11.	20.	16.
Total Coliform (M.P.N.)	L 240	460	43
Fecal Coliform (M.P.N.)	—	43	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES October 17/73	December 6/73	January 1[illegible]/74
Turbidity	7.5	4.2	6.0
Temperature (Field) °C	1.1	—	
Temperature (Lab) °C	20.5	17.6	24.3
Colour	50.	15.	60.
pH	8.0	7.9	7.2
Chloride (Cl) mg/l	1.2	18.	1.4
Copper (Cu) mg/l	L 0.001	0.005	L 0.001
Fluoride (F) mg/l	0.06	0.11	0.06
Iron (Fe) mg/l	L 0.04	L 0.04	0.33
Lead (Pb) mg/l	L 0.008	L 0.004	L 0.003
Manganese (Mn) mg/l	L 0.010	L 0.008	L 0.02
Nitrogen T. Kjeldahl (N) mg/l	0.9	0.9	0.9
Nitrogen Nitrate, Nitrite (N) mg/l	L 0.01	0.11	0.02
Phosphorus Total (P) mg/l	0.008	0.027	0.024
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	—
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	—
Potassium (K) mg/l	0.7	2.3	0.8
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.04	L 0.03	L 0.04
Zinc (Zn) mg/l	L 0.002	0.004	0.003
Sodium (Na) mg/l	2.8	17.	3.5
Silica (SiO_2) mg/l	3.8	1.1	5.8
Sulphate (SO_4) mg/l	2.4	27.	4.3
Calcium (Ca) mg/l	23.	38.	28.
Hardness Total ($CaCO_3$) mg/l	76.	135.	103.
Alkalinity Total ($CaCO_3$) mg/l	71.	111.	98.
Specific Conductance, micromho/cm	144.	338.	203.
Total Inorganic Carbon (C) mg/l	13.	24.	18.
Total Organic Carbon (C) mg/l	17.	8.	19.
Total Coliform (M.P.N.)	93.	0	9
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 20 TAYLOR RIVER @ THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES March 7/74		
Turbidity	5.5		
Temperature (Field) °C	—		
Temperature (Lab) °C	20.4		
Colour	90.		
pH	7.1		
Chloride (Cl) mg/l	4.4		
Copper (Cu) mg/l	0.006		
Fluoride (F) mg/l	0.07		
Iron (Fe) mg/l	0.77		
Lead (Pb) mg/l	L 0.002		
Manganese (Mn) mg/l	0.06		
Nitrogen T. Kjeldahl (N) mg/l	2.1		
Nitrogen Nitrate, Nitrite (N) mg/l	0.13		
Phosphorus Total (P) mg/l	0.32		
Phosphorus Ortho (P) mg/l	0.003		
Inorganic Phosphorus (P) mg/l	0.009		
Potassium (K) mg/l	2.2		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	L 0.04		
Zinc (Zn) mg/l	0.008		
Sodium (Na) mg/l	7.6		
Silica (SiO_2) mg/l	8.1		
Sulphate (SO_4) mg/l	9.5		
Calcium (Ca) mg/l	49.		
Hardness Total ($CaCO_3$) mg/l	176.		
Alkalinity Total ($CaCO_3$) mg/l	168.		
Specific Conductance, micromho/cm	348.		
Total Inorganic Carbon (C) mg/l	30.		
Total Organic Carbon (C) mg/l	36.		
Total Coliform (M.P.N.)			
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

STATION#20 TAYLOR RIVER AT THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES June 6, 1974	July 24, 1974	August 6, 1974
Turbidity	26.	30.0	27.
Temperature (Field)°C	—	16.7	24.
Temperature (Lab)°C	24.0	23.2	22.1
Colour	80.	50.	70.
pH	7.6	7.4	7.9
Chloride (Cl) mg/l	0.9	1.2	1.1
Copper (Cu) mg/l	0.001	0.001	0.002
Fluoride (F) mg/l	L0.05	0.05	0.06
Iron (Fe) mg/l	0.27	0.23	0.05
Lead (Pb) mg/l	L0.004	0.005	L0.00[illegible]
Manganese (Mn) mg/l	L0.010	0.011	L0.010
Nitrogen T. Kjeldahl (N) mg/l	0.7	0.7	1.
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.23	0.01
Phosphorus Total (P) mg/l	0.048	0.026	0.025
Phosphorus Ortho (P) mg/l	0.010	L0.003	L0.003
Inorganic Phosphorus (P) mg/l	0.010	0.003	0.006
Potassium (K) mg/l	0.8	0.5	0.6
Non Filterable Residue, mg/l	26.	—	20.
Fixed Residue, mg/l	19.	—	L1.
Mercury (Hg) mg/l	L0.05	L0.05	L0.05
Zinc (Zn) mg/l	L0.001	0.002	0.004
Sodium (Na) mg/l	2.2	2.3	2.6
Silica (SiO_2) mg/l	1.7	2.3	3.8
Sulphate (SO_4) mg/l	4.6	3.4	5.1
Calcium (Ca) mg/l	17.	20.	23.
Hardness Total ($CaCO_3$) mg/l	60.	67.	74.
Alkalinity Total ($CaCO_3$) mg/l	53.	60.	69.
Specific Conductance, micromho/cm	117.	130.	142.
Total Inorganic Carbon (C) mg/l	12.	13.	15.
Total Organic Carbon (C) mg/l	18.	17.	18.
Total Coliform (M.P.N.)	93.	93.	43.
Fecal Coliform (M.P.N.)	4.	9.	9.

N.B.: June 6, 1974: Cation-Anion balance not within reliable limits

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION#20 TAYLOR RIVER AT THOMPSON (PIPE LAKE)

CONSTITUENTS	SAMPLING DATES Oct. 4, 1974		
Turbidity	5.4		
Temperature (Field) °C	4.0		
Temperature (Lab) °C	17.9		
Colour	30.		
pH	7.7		
Chloride (Cl) mg/l	0.8		
Copper (Cu) mg/l	L0.001		
Fluoride (F) mg/l	L0.05		
Iron (Fe) mg/l	L0.04		
Lead (Pb) mg/l	0.004		
Manganese (Mn) mg/l	L0.01		
Nitrogen T. Kjeldahl (N) mg/l	0.7		
Nitrogen Nitrate, Nitrite (N) mg/l	L0.01		
Phosphorus Total (P) mg/l	0.014		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	L0.003		
Potassium (K) mg/l	0.6		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) ug/l	0.07		
Zinc (Zn) mg/l	0.002		
Sodium (Na) mg/l	2.6		
Silica (SiO_2) mg/l	3.2		
Sulphate (SO_4) mg/l	3.6		
Calcium (Ca) mg/l	17.		
Hardness Total ($CaCO_3$) mg/l	65.		
Alkalinity Total ($CaCO_3$) mg/l	61.		
Specific Conductance, micromho/cm	128.		
Total Inorganic Carbon (C) mg/l	14.		
Total Organic Carbon (C) mg/l	15.		
Total Coliform (M.P.N.)	75.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION # 21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES Jul/ 12/72	August 16/72	September [illegible]
Turbidity	5.0	4.5	8.8
Temperature (Field)°C	17.8	—	--
Temperature (Lab)°C	—	23.5	22.
Colour	50	20	30
pH	—	8.0	8.1
Chloride (Cl) mg/l	0.6	1.0	0.8
Copper (Cu) mg/l	0.001	0.007	L 0.001
Fluoride (F) mg/l	0.06	L 0.05	0.08
Iron (Fe) mg/l	0.04	0.22	0.04
Lead (Pb) mg/l	L 0.004	L 0.006	L 0.00[illegible]
Manganese (Mn) mg/l	L 0.010	L 0.005	L 0.006
Nitrogen T. Kjeldahl (N) mg/l	0.56	0.56	0.73
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.60	1.8
Phosphorus Total (P) mg/l	0.021	0.016	0.028
Phosphorus Ortho (P) mg/l	0.003	0.003	L 0.005
Inorganic Phosphorus (P) mg/l	0.003	0.004	0.010
Potassium (K) mg/l	0.9	0.7	0.7
Non Filterable Residue, mg/l	1.6	1.2	10.
Fixed Residue, mg/l	L 0.1	L 0.1	3.2
Mercury (Hg) µg/l	0.07	0.5*	0.05
Zinc (Zn) mg/l	0.002	0.030	L 0.02
Sodium (Na) mg/l	2.1	2.2	2.4
Silica (SiO_2) mg/l	2.9	2.8	3.4
Sulphate (SO_4) mg/l	4.0	4.9	9.3
Calcium (Ca) mg/l	—	20.5	26.2
Hardness Total ($CaCO_3$) mg/l	—	74.5	84.1
Alkalinity Total ($CaCO_3$) mg/l	—	67.7	72.7
Specific Conductance, micromho/cm	135.	144.	147.
Total Inorganic Carbon (C) mg/l	10.	7.0	8.
Total Organic Carbon (C) mg/l	14.	11.0	15.0
Total Coliform (M.P.N.)	4.	--	93
Fecal Coliform (M.P.N.)	—	--	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Sample contaminated

STATION #21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES October 10/72	December 6/72	January 22/73
Turbidity	7.5	7.0	4.0
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	22.5	21.9	25.1
Colour	30.	30.	20.
pH	7.8	8.0	7.9
Chloride (Cl) mg/l	0.7	1.2	0.8
Copper (Cu) mg/l	L 0.002	0.002	0.002
Fluoride (F) mg/l	0.05	0.05	0.06
Iron (Fe) mg/l	L 0.04	0.04	—
Lead (Pb) mg/l	L 0.008	L 0.006	L 0.006
Manganese (Mn) mg/l	L 0.008	L 0.005	0.021
Nitrogen T. Kjeldahl (N) mg/l	0.71	0.84	0.74
Nitrogen Nitrate, Nitrite (N) mg/l	0.14	3.6	0.17
Phosphorus Total (P) mg/l	0.027	0.035	0.020
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.007
Inorganic Phosphorus (P) mg/l	0.006	L 0.003	0.008
Potassium (K) mg/l	0.8	1.3	0.9
Non Filterable Residue, mg/l	L 0.1	10.2	—
Fixed Residue, mg/l	L 0.1	4.8	—
Mercury (Hg) µg/l	1.3	0.22	—
Zinc (Zn) mg/l	0.003	0.001	0.003
Sodium (Na) mg/l	2.2	3.1	2.3
Silica (SiO_2) mg/l	3.3	7.6	6.8
Sulphate (SO_4) mg/l	4.4	3.9	5.7
Calcium (Ca) mg/l	23.7	31.9	24.6
Hardness Total ($CaCO_3$) mg/l	74.9	108.	87
Alkalinity Total ($CaCO_3$) mg/l	71.8	92.9	86.7
Specific Conductance, micromho/cm	148	244	182
Total Inorganic Carbon (C) mg/l	11.	24.	21.
Total Organic Carbon (C) mg/l	7.	12.	7.
Total Coliform (M.P.N.)	9.	43	—
Fecal Coliform (M.P.N.)	0	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES February 27/73	March 28/73	June 11/73
Turbidity	5.3		5.6
Temperature (Field)°C	0.0		—
Temperature (Lab)°C	23.0		24.0
Colour	25.0		20.0
pH	7.6		7.8
Chloride (Cl) mg/l	1.2		0.7
Copper (Cu) mg/l	0.002		0.003
Fluoride (F) mg/l	0.07		0.06
Iron (Fe) mg/l	0.09		0.03
Lead (Pb) mg/l	—		0.005
Manganese (Mn) mg/l	0.022		L 0.005
Nitrogen T. Kjeldahl (N) mg/l	0.71		0.58
Nitrogen Nitrate, Nitrite (N) mg/l	0.10		0.15
Phosphorus Total (P) mg/l	0.026		0.016
Phosphorus Ortho (P) mg/l	0.003		L 0.003
Inorganic Phosphorus (P) mg/l	0.004		L 0.004
Potassium (K) mg/l	1.3		0.8
Non Filterable Residue, mg/l	3.2		—
Fixed Residue, mg/l	1.2		—
Mercury (Hg) µg/l	0.05		L 0.02
Zinc (Zn) mg/l	0.004		L 0.002
Sodium (Na) mg/l	2.8		2.2
Silica (SiO_2) mg/l	6.9		26
Sulphate (SO_4) mg/l	7.1		4.3
Calcium (Ca) mg/l	27.5		18.7
Hardness Total ($CaCO_3$) mg/l	95.6		65.4
Alkalinity Total ($CaCO_3$) mg/l	89.2		58.6
Specific Conductance, micromho/cm	167.		131.
Total Inorganic Carbon (C) mg/l	20		13
Total Organic Carbon (C) mg/l	11		11
Total Coliform (M.P.N.)	9	240	0
Fecal Coliform (M.P.N.)	0	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES July 11/73	August 13/73	September 21/73
Turbidity	18		8.7
Temperature (Field) °C	—		—
Temperature (Lab) °C	26.9		22.0
Colour	40.		30.
pH	8.1		7.7
Chloride (Cl) mg/l	0.9		0.9
Copper (Cu) mg/l	L 0.002		L 0.001
Fluoride (F) mg/l	0.05		0.06
Iron (Fe) mg/l	0.12		L 0.04
Lead (Pb) mg/l	L 0.004		L 0.005
Manganese (Mn) mg/l	L 0.009		L 0.009
Nitrogen T. Kjeldahl (N) mg/l	—		0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.18		0.14
Phosphorus Total (P) mg/l	0.021		0.022
Phosphorus Ortho (P) mg/l	0.004		L 0.003
Inorganic Phosphorus (P) mg/l	0.004		L 0.003
Potassium (K) mg/l	0.9		0.8
Non Filterable Residue, mg/l	—		—
Fixed Residue, mg/l	—		—
Mercury (Hg) µg/l	0.04		0.05
Zinc (Zn) mg/l	L 0.001		0.002
Sodium (Na) mg/l	2.3		2.3
Silica (SiO_2) mg/l	2.8		3.1
Sulphate (SO_4) mg/l	3.3		3.3
Calcium (Ca) mg/l	16.		2.4
Hardness Total ($CaCO_3$) mg/l	62.		77
Alkalinity Total ($CaCO_3$) mg/l	53		73
Specific Conductance, micromho/cm	116		143
Total Inorganic Carbon (C) mg/l	9.		14
Total Organic Carbon (C) mg/l	14.		14.
Total Coliform (M.P.N.)	0	15	—
Fecal Coliform (M.P.N.)	0	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES October 15/73	December 17/73	February 13/74
Turbidity	8.3		5.0
Temperature (Field)°C	—		0.0
Temperature (Lab)°C	26.4		17.1
Colour	45		25
pH	7.6		7.3
Chloride (Cl) mg/l	1.5		1.5
Copper (Cu) mg/l	L 0.001		0.004
Fluoride (F) mg/l	L 0.05		0.08
Iron (Fe) mg/l	0.10		0.11
Lead (Pb) mg/l	L 0.003		L 0.003
Manganese (Mn) mg/l	L 0.008		0.02
Nitrogen T. Kjeldahl (N) mg/l	0.6		0.8
Nitrogen Nitrate, Nitrite (N) mg/l	0.04		0.13
Phosphorus Total (P) mg/l	0.020		0.020
Phosphorus Ortho (P) mg/l	L 0.003		L 0.003
Inorganic Phosphorus (P) mg/l	0.006		0.004
Potassium (K) mg/l	0.9		1.1
Non Filterable Residue, mg/l	—		—
Fixed Residue, mg/l	—		—
Mercury (Hg) µg/l	L 0.04		0.02
Zinc (Zn) mg/l	0.082		0.005
Sodium (Na) mg/l	2.4		2.8
Silica (SiO_2) mg/l	4.0		5.0
Sulphate (SO_4) mg/l	0.8		4.0
Calcium (Ca) mg/l	17		28.
Hardness Total ($CaCO_3$) mg/l	63		97.
Alkalinity Total ($CaCO_3$) mg/l	57		89
Specific Conductance, micromho/cm	117		194
Total Inorganic Carbon (C) mg/l	10		17
Total Organic Carbon (C) mg/l	11		10.
Total Coliform (M.P.N.)	0	240	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 21 FOOTPRINT RIVER ABOVE THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES July 22, 1974	July 23, 1974	
Turbidity	9.2	5.	
Temperature (Field) °C	15.6	21.61	
Temperature (Lab) °C	23.4	21.1	
Colour	20.	10.	
pH	7.6	7.5	
Chloride (Cl) mg/l	2.1	1.	
Copper (Cu) mg/l	.003	L.001	
Fluoride (F) mg/l	L.05	.06	
Iron (Fe) mg/l	L.04	L.04	
Lead (Pb) mg/l	L.004	L.004	
Manganese (Mn) mg/l	L.01	L.01	
Nitrogen T. Kjeldahl (N) mg/l	.6	.5	
Nitrogen Nitrate, Nitrite (N) mg/l	.02	.06	
Phosphorus Total (P) mg/l	.015	.013	
Phosphorus Ortho (P) mg/l	L.003	L.003	
Inorganic Phosphorus (P) mg/l	.01	L.003	
Potassium (K) mg/l	.9	1.1	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) microgram/l	.05	L.05	
Zinc (Zn) mg/l	.002	.005	
Sodium (Na) mg/l	2.3	2.3	
Silica (SiO_2) mg/l	2.7	3.0	
Sulphate (SO_4) mg/l	3.5	3.5	
Calcium (Ca) mg/l	20.	21.	
Hardness Total ($CaCO_3$) mg/l	74.	74.	
Alkalinity Total ($CaCO_3$) mg/l	70.	70.	
Specific Conductance, micromho/cm	139.	149.	
Total Inorganic Carbon (C) mg/l	16.	15.	
Total Organic Carbon (C) mg/l	11.	13.	
Total Coliform (M.P.N.)	9.	9.	
Fecal Coliform (M.P.N.)	0.	0.	

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, Disregard this data

STATION # 22 Burntwood River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Aug. 1/72	** Aug. 16/72	Sept. 27/72
Turbidity	15	15	23
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	23.4	23.5	22.0
Colour	40	60	60
pH	7.9	7.8	8.0
Chloride (Cl) mg/l	0.6	0.7	0.9
Copper (Cu) mg/l	0.001	0.008	1.1
Fluoride (F) mg/l	0.08	0.07	L0.05
Iron (Fe) mg/l	0.08	0.18	0.07
Lead (Pb) mg/l	L0.002	L0.006	0.8
Manganese (Mn) mg/l	L0.008	0.005	0.02
Nitrogen T. Kjeldahl (N) mg/l	0.98	0.95	0.74
Nitrogen Nitrate, Nitrite (N) mg/l	0.39	0.32	1.4
Phosphorus Total (P) mg/l	0.030	0.034	0.034
Phosphorus Ortho (P) mg/l	L0.003	0.005	0.005
Inorganic Phosphorus (P) mg/l	0.004	0.006	0.008
Potassium (K) mg/l	0.7	0.7	0.7
Non Filterable Residue, mg/l	13.2	6.5	16
Fixed Residue, mg/l	0.8	2.5	8
Mercury (Hg) µg/l	0.12	0.14 *	0.17
Zinc (Zn) mg/l	0.002	L0.005	0.68
Sodium (Na) mg/l	2.0	2.1	3.0
Silica (SiO_2) mg/l	3.3	3.5	4.6
Sulphate (SO_4) mg/l	4.53	2.5	2.2
Calcium (Ca) mg/l	15.7	11.8	15.2
Hardness Total ($CaCO_3$) mg/l	57.7	50.2	51.1
Alkalinity Total ($CaCO_3$) mg/l	49.1	41.7	44.1
Specific Conductance, micromho/cm	111	91	107
Total Inorganic Carbon (C) mg/l	6.0	6	16
Total Organic Carbon (C) mg/l	10.0	18.0	19
Total Coliform (M.P.N.)	4	-	1100
Fecal Coliform (M.P.N.)	0	-	0

LEGEND MPN = Most probable number per 100 ml

L = Less than * = unreliable value

** = cation anion balance not within acceptable range

STATION # 22 Burntwood River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Oct. 10/72	Dec. 6/72	Jan. 22/73
Turbidity	20	7	9.4
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	22.5	22.0	25.1
Colour	60	50	40
pH	7.7	8.0	7.6
Chloride (Cl) mg/l	0.8	1.0	0.9
Copper (Cu) mg/l	0.14	0.002	0.002
Fluoride (F) mg/l	0.05	0.05	0.07
Iron (Fe) mg/l	0.07	0.06	0.10
Lead (Pb) mg/l	0.012	LO.006	0.00[illegible]
Manganese (Mn) mg/l	0.008	LO.005	LO.[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.68	0.54	0.6[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.25	0.06	0.5[illegible]
Phosphorus Total (P) mg/l	0.027	0.033	0.03[illegible]
Phosphorus Ortho (P) mg/l	0.007	0.005	0.00[illegible]
Inorganic Phosphorus (P) mg/l	0.007	0.007	0.00[illegible]
Potassium (K) mg/l	0.8	1.0	0.9
Non Filterable Residue, mg/l	8.0	3.2	-
Fixed Residue, mg/l	0.4	0.4	-
Mercury (Hg) µg/l	1.4	LO.07	-
Zinc (Zn) mg/l	0.15	LO.001	0.002
Sodium (Na) mg/l	2.2	2.4	2.7
Silica (SiO_2) mg/l	3.3	3.5	2.9
Sulphate (SO_4) mg/l	1.8	1.8	4.6
Calcium (Ca) mg/l	14.9	19.0	13.3
Hardness Total ($CaCO_3$) mg/l	49.3	60.2	49.3
Alkalinity Total ($CaCO_3$) mg/l	42.5	58.5	46.6
Specific Conductance, micromho/cm	93.5	124	99.6
Total Inorganic Carbon (C) mg/l	9	13	11
Total Organic Carbon (C) mg/l	14	12	12
Total Coliform (M.P.N.)	23	0	-
Fecal Coliform (M.P.N.)	4	0	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 22 Burntwood River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Feb. 27/73	Mar. 28/73	June 11/73
Turbidity	7.0	9.2	22
Temperature (Field) °C	0	-	-
Temperature (Lab) °C	23.0	23.3	24.9
Colour	40	50	5[illegible]
pH	7.9	7.7	7.6
Chloride (Cl) mg/l	1.2	1.6	0.7
Copper (Cu) mg/l	0.001	L0.003	L0.001
Fluoride (F) mg/l	0.07	0.06	0.07
Iron (Fe) mg/l	0.10	0.14	0.10
Lead (Pb) mg/l	-	L0.004	L0.0[illegible]
Manganese (Mn) mg/l	L0.006	L0.008	L0.[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.56	0.57	0.[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.15	0.24	0.[illegible]
Phosphorus Total (P) mg/l	0.032	0.025	0.0[illegible]
Phosphorus Ortho (P) mg/l	0.005	0.008	0.00[illegible]
Inorganic Phosphorus (P) mg/l	0.007	0.009	0.0[illegible]
Potassium (K) mg/l	1.1	1.2	0.[illegible]
Non Filterable Residue, mg/l	2.4	-	11
Fixed Residue, mg/l	L0.1	-	7.0
Mercury (Hg) µg/l	L0.03	0.05	-
Zinc (Zn) mg/l	0.005	L0.002	L0.002
Sodium (Na) mg/l	2.7	2.6	2.[illegible]
Silica (SiO_2) mg/l	4.4	3.6	2.7
Sulphate (SO_4) mg/l	4.1	3.8	5.2
Calcium (Ca) mg/l	20.8	15.4	13.4
Hardness Total ($CaCO_3$) mg/l	68.0	56.4	45.0
Alkalinity Total ($CaCO_3$) mg/l	62.9	49.9	42.5
Specific Conductance, micromho/cm	146	112	96
Total Inorganic Carbon (C) mg/l	15	11	9
Total Organic Carbon (C) mg/l	12	15	13
Total Coliform (M.P.N.)	0	1240	9[illegible]
Fecal Coliform (M.P.N.)	0	0	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 22 Burntwood River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES July 10/73	Aug. 13/73	Sept. 21/73
Turbidity	11	15	13
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	26.0	23.4	22.1
Colour	40	50	60
pH	7.8	7.7	7.8
Chloride (Cl) mg/l	1.1	1.6	1.1
Copper (Cu) mg/l	0.002	0.003	0.002
Fluoride (F) mg/l	L0.05	0.05	0.21
Iron (Fe) mg/l	0.05	0.95	0.12
Lead (Pb) mg/l	L0.004	L0.005	L0.00[illegible]
Manganese (Mn) mg/l	L0.009	0.031	L0.00[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.80	0.5	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	L0.01	0.04
Phosphorus Total (P) mg/l	0.014	0.022	0.023
Phosphorus Ortho (P) mg/l	L0.003	-	L0.00[illegible]
Inorganic Phosphorus (P) mg/l	L0.003	-	0.00[illegible]
Potassium (K) mg/l	1.1	1.0	0.7
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) ug/l	0.06	0.08	L0.05
Zinc (Zn) mg/l	0.001	0.006	0.002
Sodium (Na) mg/l	2.4	2.5	2.7
Silica (SiO_2) mg/l	2.9	3.7	5.0
Sulphate (SO_4) mg/l	2.6	4.2	1.1
Calcium (Ca) mg/l	18	21	18
Hardness Total ($CaCO_3$) mg/l	58	59	61
Alkalinity Total ($CaCO_3$) mg/l	56	56	58
Specific Conductance, micromho/cm	120	111	117
Total Inorganic Carbon (C) mg/l	9	-	12
Total Organic Carbon (C) mg/l	12	-	17
Total Coliform (M.P.N.)	9	7	-
Fecal Coliform (M.P.N.)	4	4	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 22 Burntwood River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Oct. 15/73	Dec. 17/73	Feb. 18/74
Turbidity	6.0	13	8.8
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	18.4	22.1	17.6
Colour	40	50	35
pH	7.6	7.2	7.4
Chloride (Cl) mg/l	1.4	1.5	1.5
Copper (Cu) mg/l	0.002	0.005	0.006
Fluoride (F) mg/l	0.05	0.08	0.08
Iron (Fe) mg/l	0.08	0.11	0.09
Lead (Pb) mg/l	L0.006	L0.004	L0.003
Manganese (Mn) mg/l	L0.008	0.010	L0.02
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.4	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.16	0.24
Phosphorus Total (P) mg/l	0.021	0.027	0.025
Phosphorus Ortho (P) mg/l	L0.003	0.005	L0.003
Inorganic Phosphorus (P) mg/l	L0.003	0.009	0.005
Potassium (K) mg/l	0.9	0.9	1.0
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	L0.04	-	L0.02
Zinc (Zn) mg/l	L0.001	0.004	0.007
Sodium (Na) mg/l	2.3	2.7	3.0
Silica (SiO_2) mg/l	2.9	3.6	3.9
Sulphate (SO_4) mg/l	1.1	3.8	4.0
Calcium (Ca) mg/l	17	17	16
Hardness Total ($CaCO_3$) mg/l	60	65	54
Alkalinity Total ($CaCO_3$) mg/l	57	47	50
Specific Conductance, micromho/cm	114	116	112
Total Inorganic Carbon (C) mg/l	12	12	12
Total Organic Carbon (C) mg/l	12	14	12
Total Coliform (M.P.N.)	15	L240	0
Fecal Coliform (M.P.N.)	0		0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 22 BURNTWOOD RIVER AT THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES April 8, 1974		
Turbidity	1.8		
Temperature (Field)°C	0.0		
Temperature (Lab)°C	13.8		
Colour	10.		
pH	7.4		
Chloride (Cl) mg/l	1.9		
Copper (Cu) mg/l	—		
Fluoride (F) mg/l	0.07		
Iron (Fe) mg/l	—		
Lead (Pb) mg/l	—		
Manganese (Mn) mg/l	—		
Nitrogen T. Kjeldahl (N) mg/l	0.8		
Nitrogen Nitrate, Nitrite (N) mg/l	0.12		
Phosphorus Total (P) mg/l	0.015		
Phosphorus Ortho (P) mg/l	—		
Inorganic Phosphorus (P) mg/l	—		
Potassium (K) mg/l	1.5		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) ug/l	—		
Zinc (Zn) mg/l	—		
Sodium (Na) mg/l	4.2		
Silica (SiO_2) mg/l	2.8		
Sulphate (SO_4) mg/l	3.0		
Calcium (Ca) mg/l	13.		
Hardness Total ($CaCO_3$) mg/l	50.		
Alkalinity Total ($CaCO_3$) mg/l	51.		
Specific Conductance, micromho/cm	111.		
Total Inorganic Carbon (C) mg/l	10.		
Total Organic Carbon (C) mg/l	12.		
Total Coliform (M.P.N.)	L2.0.		
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION#22 BURNTWOOD RIVER @ THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES July 23, 1974		
Turbidity	18.		
Temperature (Field) °C	21.11		
Temperature (Lab) °C	22.0		
Colour	40.		
pH	7.5		
Chloride (Cl) mg/l	1.		
Copper (Cu) mg/l	0.001		
Fluoride (F) mg/l	0.06		
Iron (Fe) mg/l	L0.04		
Lead (Pb) mg/l	0.004		
Manganese (Mn) mg/l	L0.01		
Nitrogen T. Kjeldahl (N) mg/l	0.3		
Nitrogen Nitrate, Nitrite (N) mg/l	0.02		
Phosphorus Total (P) mg/l	0.016		
Phosphorus Ortho (P) mg/l	L0.003		
Inorganic Phosphorus (P) mg/l	L0.003		
Potassium (K) mg/l	1.		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) microgram/l	L0.05		
Zinc (Zn) mg/l	0.004		
Sodium (Na) mg/l	2.5		
Silica (SiO_2) mg/l	2.7		
Sulphate (SO_4) mg/l	2.9		
Calcium (Ca) mg/l	14.		
Hardness Total ($CaCO_3$) mg/l	53.		
Alkalinity Total ($CaCO_3$) mg/l	50.		
Specific Conductance, micromho/cm	107.		
Total Inorganic Carbon (C) mg/l	10.		
Total Organic Carbon (C) mg/l	16.		
Total Coliform (M.P.N.)	9.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION # 23 Rat River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES July 12/72	Aug. 10/72	Sept. 27/72
Turbidity	6.4	5.5	6.4
Temperature (Field) °C	64	-	40
Temperature (Lab) °C	23.8	23.5	23.5
Colour	50	30	30
pH	8.0	7.8	8.0
Chloride (Cl) mg/l	0.7	0.6	0.9
Copper (Cu) mg/l	0.001	0.004	0.006
Fluoride (F) mg/l	0.06	0.06	0.06
Iron (Fe) mg/l	0.07	0.27	0.06
Lead (Pb) mg/l	L0.004	L0.006	L0.006
Manganese (Mn) mg/l	L0.010	L0.005	L0.006
Nitrogen T. Kjeldahl (N) mg/l	0.54	0.70	0.44
Nitrogen Nitrate, Nitrite (N) mg/l	0.04	1.4	0.47
Phosphorus Total (P) mg/l	0.025	0.027	0.030
Phosphorus Ortho (P) mg/l	0.003	0.004	0.004
Inorganic Phosphorus (P) mg/l	0.007	0.005	0.011
Potassium (K) mg/l	0.9	0.5	0.8
Non Filterable Residue, mg/l	6.0	70	8.0
Fixed Residue, mg/l	5.2	L0.1	2.0
Mercury (Hg) µg/l	-	L0.06	1.7*
Zinc (Zn) mg/l	0.002	0.062	L0.02
Sodium (Na) mg/l	1.9	1.6	2.0
Silica (SiO_2) mg/l	2.8	3.0	3.8
Sulphate (SO_4) mg/l	3.4	2.5	0.80
Calcium (Ca) mg/l	16.2	15.3	17.0
Hardness Total ($CaCO_3$) mg/l	59.4	57.5	55.8
Alkalinity Total ($CaCO_3$) mg/l	53.2	47.2	53.5
Specific Conductance, micromho/cm	113	108	115
Total Inorganic Carbon (C) mg/l	9	6	7
Total Organic Carbon (C) mg/l	13	11	10
Total Coliform (M.P.N.)	23	-	43
Fecal Coliform (M.P.N.)	-	-	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = disregard this value, acid contaminated

STATION # 23 Rat River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Oct. 10/72	Dec. 6/72	Jan. 22/73
Turbidity	7.2	5.8	4.2
Temperature (Field)°C	-	-	0
Temperature (Lab)°C	22.6	21.9	25.1
Colour	30	40	40
pH	7.8	-	7.9
Chloride (Cl) mg/l	0.8	1.0	0.8
Copper (Cu) mg/l	L0.002	L0.002	0.002
Fluoride (F) mg/l	0.05	0.05	0.05
Iron (Fe) mg/l	L0.04	0.05	-
Lead (Pb) mg/l	L0.008	L0.006	L0.008
Manganese (Mn) mg/l	L0.008	L0.005	0.01
Nitrogen T. Kjeldahl (N) mg/l	0.64	0.54	0.52
Nitrogen Nitrate, Nitrite (N) mg/l	0.28	-	0.1c
Phosphorus Total (P) mg/l	0.028	0.031	0.01
Phosphorus Ortho (P) mg/l	0.003	0.006	0.00
Inorganic Phosphorus (P) mg/l	0.003	0.007	0.01
Potassium (K) mg/l	0.7	1.0	0.7
Non Filterable Residue, mg/l	12.5	2.8	-
Fixed Residue, mg/l	2.5	1.2	-
Mercury (Hg) µg/l	1.4*	0.07	-
Zinc (Zn) mg/l	0.002	L0.001	0.002
Sodium (Na) mg/l	1.7	2.3	2.3
Silica (SiO_2) mg/l	3.6	3.9	4.2
Sulphate (SO_4) mg/l	2.3	1.1	2.4
Calcium (Ca) mg/l	17.1	19.7	18.4
Hardness Total ($CaCO_3$) mg/l	58.4	65.4	63.1
Alkalinity Total ($CaCO_3$) mg/l	52.0	-	62.4
Specific Conductance, micromho/cm	112	134	128
Total Inorganic Carbon (C) mg/l	11	13	15
Total Organic Carbon (C) mg/l	10	12	10
Total Coliform (M.P.N.)	9	9	-
Fecal Coliform (M.P.N.)	0	0	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = disregard this value, acid contamination

STATION # 23 Rat River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Feb. 27/73	Mar. 28/73	June 11/73
Turbidity	5.0		3.4
Temperature (Field) °C	0		-
Temperature (Lab) °C	22.5		24.0
Colour	50		25
pH	7.8		7.8
Chloride (Cl) mg/l	1.1		0.8
Copper (Cu) mg/l	0.002		0.001
Fluoride (F) mg/l	0.07		0.06
Iron (Fe) mg/l	0.06		0.03
Lead (Pb) mg/l	-		LO.0[illegible]
Manganese (Mn) mg/l	0.011		LO.0[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.62		0.5[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.09		0.02
Phosphorus Total (P) mg/l	0.021		0.01[illegible]
Phosphorus Ortho (P) mg/l	0.007		LO.0[illegible]
Inorganic Phosphorus (P) mg/l	0.010		0.00[illegible]
Potassium (K) mg/l	1.1		0.8
Non Filterable Residue, mg/l	2.8		-
Fixed Residue, mg/l	0.4		-
Mercury (Hg) µg/l	0.16		LO.02
Zinc (Zn) mg/l	0.002		0.002
Sodium (Na) mg/l	2.4		2.2
Silica (SiO_2) mg/l	4.9		3.0
Sulphate (SO_4) mg/l	4.1		3.8
Calcium (Ca) mg/l	19.8		15.5
Hardness Total ($CaCO_3$) mg/l	70.3		55.0
Alkalinity Total ($CaCO_3$) mg/l	66.0		51.6
Specific Conductance, micromho/cm	139		112
Total Inorganic Carbon (C) mg/l	15		10
Total Organic Carbon (C) mg/l	1		10
Total Coliform (M.P.N.)	93	L240	15
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 23 Rat River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES July 11/73	Aug. 13/73	Sept. 21/73
Turbidity	5.5	2.8	7.9
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	26.0	23.8	22.2
Colour	20	35	30
pH	7.9	7.4	7.8
Chloride (Cl) mg/l	0.9	1.4	0.9
Copper (Cu) mg/l	0.002	L0.002	L0.001
Fluoride (F) mg/l	L0.05	0.06	0.07
Iron (Fe) mg/l	L0.05	0.36	0.11
Lead (Pb) mg/l	L0.004	L0.005	L0.005
Manganese (Mn) mg/l	L0.009	0.024	L0.009
Nitrogen T. Kjeldahl (N) mg/l	1.0	0.4	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.10	0.02	0.04
Phosphorus Total (P) mg/l	0.010	0.019	0.028
Phosphorus Ortho (P) mg/l	0.003	-	L0.003
Inorganic Phosphorus (P) mg/l	0.003	-	0.003
Potassium (K) mg/l	0.9	1.0	0.9
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	0.05	0.37	L0.05
Zinc (Zn) mg/l	L0.001	0.002	0.002
Sodium (Na) mg/l	2.1	2.2	2.1
Silica (SiO_2) mg/l	3.2	3.6	3.8
Sulphate (SO_4) mg/l	2.8	3.5	3.4
Calcium (Ca) mg/l	19	20	19
Hardness Total ($CaCO_3$) mg/l	59	62	61
Alkalinity Total ($CaCO_3$) mg/l	57	59	59
Specific Conductance, micromho/cm	122	118	118
Total Inorganic Carbon (C) mg/l	11	-	12
Total Organic Carbon (C) mg/l	11	-	12
Total Coliform (M.P.N.)	4	9	-
Fecal Coliform (M.P.N.)	0	0	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 23 Rat River at Threepoint Lake

CONSTITUENTS	SAMPLING DATES Oct. 15/73	Dec. 17/73	Feb. 18/74
Turbidity	7.2		7.1
Temperature (Field) °C	-		0
Temperature (Lab) °C	17.7		17.0
Colour	35		35
pH	7.6		7.4
Chloride (Cl) mg/l	1.4		1.7
Copper (Cu) mg/l	L0.001		0.007
Fluoride (F) mg/l	L0.05		0.10
Iron (Fe) mg/l	L0.04		0.11
Lead (Pb) mg/l	L0.006		L0.003
Manganese (Mn) mg/l	L0.008		0.04
Nitrogen T. Kjeldahl (N) mg/l	0.4		0.9
Nitrogen Nitrate, Nitrite (N) mg/l	0.02		0.19
Phosphorus Total (P) mg/l	0.019		0.029
Phosphorus Ortho (P) mg/l	L0.003		L0.003
Inorganic Phosphorus (P) mg/l	0.005		0.005
Potassium (K) mg/l	0.9		1.1
Non Filterable Residue, mg/l	-		-
Fixed Residue, mg/l	-		-
Mercury (Hg) µg/l	L0.04		0.10
Zinc (Zn) mg/l	0.001		0.008
Sodium (Na) mg/l	2.2		3.0
Silica (SiO_2) mg/l	3.2		4.6
Sulphate (SO_4) mg/l	0.9		3.6
Calcium (Ca) mg/l	18		23
Hardness Total ($CaCO_3$) mg/l	61		80
Alkalinity Total ($CaCO_3$) mg/l	57		73
Specific Conductance, micromho/cm	115		153
Total Inorganic Carbon (C) mg/l	12		13
Total Organic Carbon (C) mg/l	9		12
Total Coliform (M.P.N.)	0	L240	0
Fecal Coliform (M.P.N.)	0	-	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 23 RAT RIVER AT THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES April 8, 1974		
Turbidity	1.9		
Temperature (Field) °C	0.5		
Temperature (Lab) °C	13.5		
Colour	15.		
pH	7.5		
Chloride (Cl) mg/l	1.5		
Copper (Cu) mg/l	—		
Fluoride (F) mg/l	0.07		
Iron (Fe) mg/l	—		
Lead (Pb) mg/l	—		
Manganese (Mn) mg/l	—		
Nitrogen T. Kjeldahl (N) mg/l	0.5		
Nitrogen Nitrate, Nitrite (N) mg/l	0.12		
Phosphorus Total (P) mg/l	0.019		
Phosphorus Ortho (P) mg/l	—		
Inorganic Phosphorus (P) mg/l	—		
Potassium (K) mg/l	1.3		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) µg/l	—		
Zinc (Zn) mg/l	—		
Sodium (Na) mg/l	3.8		
Silica (SiO_2) mg/l	2.5		
Sulphate (SO_4) mg/l	2.8		
Calcium (Ca) mg/l	13.		
Hardness Total ($CaCO_3$) mg/l	50.		
Alkalinity Total ($CaCO_3$) mg/l	49.		
Specific Conductance, micromho/cm	106.		
Total Inorganic Carbon (C) mg/l	14.		
Total Organic Carbon (C) mg/l	12.		
Total Coliform (M.P.N.)	L240.		
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 23 RAT RIVER @ THREEPOINT LAKE

CONSTITUENTS	SAMPLING DATES		
	July 23, 1974		
Turbidity	7.		
Temperature (Field)°C	21.11		
Temperature (Lab)°C	22.8		
Colour	30.		
pH	7.9		
Chloride (Cl) mg/l	1.6		
Copper (Cu) mg/l	.002		
Fluoride (F) mg/l	.06		
Iron (Fe) mg/l	L.04		
Lead (Pb) mg/l	L.004		
Manganese (Mn) mg/l	L.01		
Nitrogen T. Kjeldahl (N) mg/l			
Nitrogen Nitrate, Nitrite (N) mg/l	.13		
Phosphorus Total (P) mg/l	.014		
Phosphorus Ortho (P) mg/l	L.003		
Inorganic Phosphorus (P) mg/l	.003		
Potassium (K) mg/l	1.1		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) microgram/l	L.05		
Zinc (Zn) mg/l	.002		
Sodium (Na) mg/l	2.3		
Silica (SiO_2) mg/l	4.0		
Sulphate (SO_4) mg/l	3.6		
Calcium (Ca) mg/l	18.		
Hardness Total ($CaCO_3$) mg/l	64.		
Alkalinity Total ($CaCO_3$) mg/l	59.		
Specific Conductance, micromho/cm	123.		
Total Inorganic Carbon (C) mg/l	13.		
Total Organic Carbon (C) mg/l	12.		
Total Coliform (M.P.N.)	9.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml.

L = Less than

* = Acid contaminated, disregard this data

STATION # 24 Churchill River at Granville Falls

CONSTITUENTS	SAMPLING DATES June 22/72	Aug. 17/72	Sept. 5/72
Turbidity	6.0	2.3	4.5
Temperature (Field) °C	-	18	-
Temperature (Lab) °C	24.0	22.8	24.8
Colour	20	10	5
pH	7.5	7.4	7.8
Chloride (Cl) mg/l	0.8	1.0	2.2
Copper (Cu) mg/l	L0.001	-	0.002
Fluoride (F) mg/l	-	-	0.08
Iron (Fe) mg/l	L0.05	-	0.26
Lead (Pb) mg/l	L0.004	-	L0.006
Manganese (Mn) mg/l	L0.010	-	L0.028
Nitrogen T. Kjeldahl (N) mg/l	-	-	-
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	L0.01	0.36
Phosphorus Total (P) mg/l	-	-	0.020
Phosphorus Ortho (P) mg/l	0.005	-	L0.003
Inorganic Phosphorus (P) mg/l	0.005	-	L0.003
Potassium (K) mg/l	1.1	1.1	1.4
Non Filterable Residue, mg/l	3.5	-	3.6
Fixed Residue, mg/l	0.5	-	0.8
Mercury (Hg) µg/l	-	-	3.40*
Zinc (Zn) mg/l	0.005	-	0.012
Sodium (Na) mg/l	2.5	3.0	4.0
Silica (SiO_2) mg/l	2.0	2.7	3.0
Sulphate (SO_4) mg/l	3.7	4.4	3.4
Calcium (Ca) mg/l	9.2	11.2	10.8
Hardness Total ($CaCO_3$) mg/l	34.4	42.7	45.3
Alkalinity Total ($CaCO_3$) mg/l	34.5	44.3	47.9
Specific Conductance, micromho/cm	80.8	97.8	105
Total Inorganic Carbon (C) mg/l	8	-	6
Total Organic Carbon (C) mg/l	7	-	11
Total Coliform (M.P.N.)	-	-	9
Fecal Coliform (M.P.N.)	-	-	4

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = sample contaminated

STATION # 24 Churchill River at Granville Falls

CONSTITUENTS	SAMPLING DATES Sept. 28/72	Dec. 6/72	Jan. 22/73
Turbidity	4.3	4.8	2.6
Temperature (Field) °C	-	0.5	0
Temperature (Lab) °C	22.0	21.9	25.1
Colour	10	30	10
pH	7.8	7.8	7.6
Chloride (Cl) mg/l	0.9	1.1	1.1
Copper (Cu) mg/l	-	0.002	0.002
Fluoride (F) mg/l	-	0.06	0.07
Iron (Fe) mg/l	-	0.04	0.02
Lead (Pb) mg/l	-	L0.006	L0.004
Manganese (Mn) mg/l	-	L0.005	L0.006
Nitrogen T. Kjeldahl (N) mg/l	-	0.41	0.71
Nitrogen Nitrate, Nitrite (N) mg/l	L0.01	0.10	0.04
Phosphorus Total (P) mg/l	-	0.024	0.018
Phosphorus Ortho (P) mg/l	-	0.005	L0.003
Inorganic Phosphorus (P) mg/l	-	0.005	0.003
Potassium (K) mg/l	1.3	1.3	1.2
Non Filterable Residue, mg/l	-	3.2	-
Fixed Residue, mg/l	-	0.4	-
Mercury (Hg) µg/l	-	0.07	-
Zinc (Zn) mg/l	-	L0.001	0.004
Sodium (Na) mg/l	3.2	3.2	3.0
Silica (SiO_2) mg/l	3.6	2.6	2.9
Sulphate (SO_4) mg/l	5.9	6.3	4.0
Calcium (Ca) mg/l	12.7	12.1	11.1
Hardness Total ($CaCO_3$) mg/l	45.2	45.2	38.7
Alkalinity Total ($CaCO_3$) mg/l	47.8	42.6	41.5
Specific Conductance, micromho/cm	101	101	87.9
Total Inorganic Carbon (C) mg/l	-	10	10
Total Organic Carbon (C) mg/l	-	9	7
Total Coliform (M.P.N.)	-	4	-
Fecal Coliform (M.P.N.)	-	-	-

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 24 Churchill River at Granville Falls

CONSTITUENTS	SAMPLING DATES Feb. 27/73	Mar. 28/73	July 11/73
Turbidity	2.1	1.9	3.8
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	22.6	23.3	24.0
Colour	10	10	10
pH	7.4	7.3	7.4
Chloride (Cl) mg/l	0.9	1.5	0.9
Copper (Cu) mg/l	0.002	L0.003	0.002
Fluoride (F) mg/l	0.11	0.10	0.08
Iron (Fe) mg/l	0.03	0.02	0.03
Lead (Pb) mg/l	-	L0.004	0.005
Manganese (Mn) mg/l	L0.008	0.018	0.008
Nitrogen T. Kjeldahl (N) mg/l	42	0.39	0.[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.12	0.08	0.[illegible]
Phosphorus Total (P) mg/l	0.012	0.013	0.01[illegible]
Phosphorus Ortho (P) mg/l	0.005	L0.003	0.0[illegible]
Inorganic Phosphorus (P) mg/l	0.007	L0.003	0.003
Potassium (K) mg/l	1.2	1.2	1.0
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	0.10	0.26	0.02
Zinc (Zn) mg/l	0.004	-	0.002
Sodium (Na) mg/l	2.6	2.6	2.3
Silica (SiO_2) mg/l	3.5	3.2	2.0
Sulphate (SO_4) mg/l	6.4	2.5	3.5
Calcium (Ca) mg/l	9.6	10.0	6.72
Hardness Total ($CaCO_3$) mg/l	37.5	33.2	26.5
Alkalinity Total ($CaCO_3$) mg/l	34.0	32.4	25.0
Specific Conductance, micromho/cm	78	75.9	62
Total Inorganic Carbon (C) mg/l	8	8	-
Total Organic Carbon (C) mg/l	8	5	-
Total Coliform (M.P.N.)	0	L240	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 24 Churchill River at Granville Falls

CONSTITUENTS	SAMPLING DATES Aug. 13/73	Sept. 10/73	Oct. 16/73
Turbidity		4.5	4.6
Temperature (Field) °C		-	-
Temperature (Lab) °C		219	18.4
Colour		20	25
pH		7.7	7.7
Chloride (Cl) mg/l		1.6	1.7
Copper (Cu) mg/l		L0.001	L0.001
Fluoride (F) mg/l		0.08	0.08
Iron (Fe) mg/l		L0.02	L0.04
Lead (Pb) mg/l		L0.005	L0.006
Manganese (Mn) mg/l		L0.009	L0.008
Nitrogen T. Kjeldahl (N) mg/l		-	0.9
Nitrogen Nitrate, Nitrite (N) mg/l		0.03	0.09
Phosphorus Total (P) mg/l		0.018	0.020
Phosphorus Ortho (P) mg/l		L0.003	L0.003
Inorganic Phosphorus (P) mg/l		L0.003	L0.003
Potassium (K) mg/l		1.5	1.4
Non Filterable Residue, mg/l		-	-
Fixed Residue, mg/l		-	-
Mercury (Hg) µg/l		0.03	L0.04
Zinc (Zn) mg/l		0.002	L0.001
Sodium (Na) mg/l		3.6	3.6
Silica (SiO_2) mg/l		3.7	1.9
Sulphate (SO_4) mg/l		2.5	1.3
Calcium (Ca) mg/l		14	16
Hardness Total ($CaCO_3$) mg/l		48	50
Alkalinity Total ($CaCO_3$) mg/l		49	57
Specific Conductance, micromho/cm		113	106
Total Inorganic Carbon (C) mg/l		11	10
Total Organic Carbon (C) mg/l		7	8
Total Coliform (M.P.N.)	23	150	0
Fecal Coliform (M.P.N.)	0	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #24 Churchill River at Granville Falls

CONSTITUENTS	SAMPLING DATES Dec. 21/73	Jan. 15/74	Feb. 18/74
Turbidity		1.6	2.5
Temperature (Field) °C		-	0.0
Temperature (Lab) °C		12.8	17.1
Colour		30	10
pH		7.2	7.6
Chloride (Cl) mg/l		1.2	2.0
Copper (Cu) mg/l		0.002	0.002
Fluoride (F) mg/l		-	0.11
Iron (Fe) mg/l		0.33	L0.04
Lead (Pb) mg/l		L0.003	L0.003
Manganese (Mn) mg/l		L0.02	L0.02
Nitrogen T. Kjeldahl (N) mg/l		0.9	0.8
Nitrogen Nitrate, Nitrite (N) mg/l		0.06	0.12
Phosphorus Total (P) mg/l		0.022	0.011
Phosphorus Ortho (P) mg/l		L0.003	L0.003
Inorganic Phosphorus (P) mg/l		L0.003	L0.003
Potassium (K) mg/l		1.2	1.4
Non Filterable Residue, mg/l		-	-
Fixed Residue, mg/l		-	-
Mercury (Hg) µg/l		L0.04	L0.02
Zinc (Zn) mg/l		0.006	L0.002
Sodium (Na) mg/l		1.9	4.0
Silica (SiO_2) mg/l		2.1	1.9
Sulphate (SO_4) mg/l		3.0	3.1
Calcium (Ca) mg/l		5.8	15
Hardness Total ($CaCO_3$) mg/l		19	53
Alkalinity Total ($CaCO_3$) mg/l		18	52
Specific Conductance, micromho/cm		52	114
Total Inorganic Carbon (C) mg/l		4	11
Total Organic Carbon (C) mg/l		11	8
Total Coliform (M.P.N.)	L240	0	9
Fecal Coliform (M.P.N.)	-	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 24 CHURCHILL RIVER ABOVE GRANVILLE FALLS

CONSTITUENTS	SAMPLING DATES April 8, 1974	June 26, 1974	July 23, 1974
Turbidity	5.6	3.5	3.8
Temperature (Field) °C	—	17.	20.0
Temperature (Lab) °C	13.7	20.8	21.9
Colour	35.	20.	5.
pH	75.	7.4	7.5
Chloride (Cl) mg/l	1.4	1.7	1.5
Copper (Cu) mg/l	—	0.003	0.001
Fluoride (F) mg/l	0.05	0.08	0.08
Iron (Fe) mg/l	—	0.30	L0.04
Lead (Pb) mg/l	—	L0.004	L0.004
Manganese (Mn) mg/l	—	0.002	L0.01
Nitrogen T. Kjeldahl (N) mg/l	0.4	0.3	0.6
Nitrogen Nitrate, Nitrite (N) mg/l	0.22	0.03	L0.01
Phosphorus Total (P) mg/l	0.022	0.018	0.013
Phosphorus Ortho (P) mg/l	—	—	L0.003
Inorganic Phosphorus (P) mg/l	—	—	L0.003
Potassium (K) mg/l	1.0	1.3	1.4
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	—	—	L0.05
Zinc (Zn) mg/l	—	0.21	0.003
Sodium (Na) mg/l	2.8	3.7	4.
Silica (SiO_2) mg/l	4.8	2.3	2.2
Sulphate (SO_4) mg/l	3.0	3.4	2.8
Calcium (Ca) mg/l	22.	12.	13.
Hardness Total ($CaCO_3$) mg/l	78.	48.	54.
Alkalinity Total ($CaCO_3$) mg/l	73.	48.	51.
Specific Conductance, micromho/cm	147.	107.	115.
Total Inorganic Carbon (C) mg/l	11.	11.	11.
Total Organic Carbon (C) mg/l	9.	10.	10.
Total Coliform (M.P.N.)	L240.		9.
Fecal Coliform (M.P.N.)			0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION# 24 CHURCHILL RIVER ABOVE GRANVILLE FALLS

CONSTITUENTS	SAMPLING DATES Sept. 16, 1974		
Turbidity	4.5		
Temperature (Field) °C	10.6		
Temperature (Lab) °C	21.5		
Colour	20.		
pH	7.9		
Chloride (Cl) mg/l	1.8		
Copper (Cu) mg/l	0.003		
Fluoride (F) mg/l	0.07		
Iron (Fe) mg/l	0.52		
Lead (Pb) mg/l	0.005		
Manganese (Mn) mg/l	0.01		
Nitrogen T. Kjeldahl (N) mg/l	0.6		
Nitrogen Nitrate, Nitrite (N) mg/l	L0.01		
Phosphorus Total (P) mg/l	0.018		
Phosphorus Ortho (P) mg/l	—		
Inorganic Phosphorus (P) mg/l	—		
Potassium (K) mg/l	1.6		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg)	—		
Zinc (Zn) mg/l	0.007		
Sodium (Na) mg/l	4.3		
Silica (SiO_2) mg/l	4.1		
Sulphate (SO_4) mg/l	3.9		
Calcium (Ca) mg/l	15.		
Hardness Total ($CaCO_3$) mg/l	56.		
Alkalinity Total ($CaCO_3$) mg/l	56.		
Specific Conductance, micromho/cm	109.		
Total Inorganic Carbon (C) mg/l	12.		
Total Organic Carbon (C) mg/l	8.		
Total Coliform (M.P.N.)			
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION # 25 CHURCHILL RIVER @ LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES July 12/72	August 22/72 **	September 27/72
Turbidity	5.0	3.2	5.4
Temperature (Field) °C	—	—	—
Temperature (Lab) °C	23.5	23.0	—
Colour	30.	15.	10.
pH	7.9	7.6	—
Chloride (Cl) mg/l	0.9	—	1.0
Copper (Cu) mg/l	0.005	0.002	0.002
Fluoride (F) mg/l	0.07	0.07	0.08
Iron (Fe) mg/l	0.12	0.05	0.03
Lead (Pb) mg/l	L 0.004	L 0.004	L 0.004
Manganese (Mn) mg/l	0.010	L 0.010	0.040
Nitrogen T. Kjeldahl (N) mg/l	0.70	—	0.54
Nitrogen Nitrate, Nitrite (N) mg/l	0.01	0.39	—
Phosphorus Total (P) mg/l	0.020	—	0.039
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	0.003
Inorganic Phosphorus (P) mg/l	L 0.003	0.003	0.004
Potassium (K) mg/l	1.0	—	2.2
Non Filterable Residue, mg/l	5.6	2.2	6.4
Fixed Residue, mg/l	1.8	0.1	3.0
Mercury (Hg) µg/l	L 0.04	L 0.04	2.1*
Zinc (Zn) mg/l	0.005	0.003	L 0.02
Sodium (Na) mg/l	2.6	—	3.2
Silica (SiO_2) mg/l	1.6	—	3.6
Sulphate (SO_4) mg/l	5.2	—	4.2
Calcium (Ca) mg/l	8.8	10.9	10.0
Hardness Total ($CaCO_3$) mg/l	36.1	43.3	50.8
Alkalinity Total ($CaCO_3$) mg/l	33.3	37.1	—
Specific Conductance, micromho/cm	75.1	79.4	94.5
Total Inorganic Carbon (C) mg/l	4.	6.	5.
Total Organic Carbon (C) mg/l	9.	9.	11.
Total Coliform (M.P.N.)	0	0	4.
Fecal Coliform (M.P.N.)	0	106.	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

** = Insufficient sample to complete analyses

* = Sample contaminated

STATION #25 CHURCHILL RIVER AT LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES		
	[illegible] 2/72	December 5/72	January 8/73
Turbidity	3.6	6.0	5.9
Temperature (Field)°C	—	—	—
Temperature (Lab)°C	2[illegible].0	21.8	26.0
Colour	10.	20.	15.
pH	7.8	7.7	7.5
Chloride (Cl) mg/l	0.9	1.0	0.8
Copper (Cu) mg/l	L 0.00[illegible]	L 0.00[illegible]	L 0.002
Fluoride (F) mg/l	0.0[illegible]	0.0[illegible]	0.07
Iron (Fe) mg/l	L 0.04	0.04	0.06
Lead (Pb) mg/l	L 0.00[illegible]	L 0.00[illegible]	L 0.006
Manganese (Mn) mg/l	L 0.01[illegible]	L 0.01[illegible]	L 0.[illegible]
Nitrogen T. Kjeldahl (N) mg/l	0.[illegible]	0.[illegible]	[illegible]
Nitrogen Nitrate, Nitrite (N) mg/l	0.[illegible]	[illegible]	0.19
Phosphorus Total (P) mg/l	0.[illegible]	0.[illegible]	0.018
Phosphorus Ortho (P) mg/l	0.[illegible]	0.[illegible]	0.008
Inorganic Phosphorus (P) mg/l	0.00[illegible]	0.00[illegible]	0.006
Potassium (K) mg/l	1.3	1.0	1.3
Non Filterable [illegible] mg/l	[illegible]	0.4	8.8
Fixed [illegible] Residue, mg/l	0.1	L 0.1	2.8
Mercury (Hg) mg/l	0.[illegible]	L 0.0[illegible]	0.18
Zinc (Zn) mg/l	0.00[illegible]	L 0.001	0.002
Sodium (Na) mg/l	3.0	3.3	3.1
Silica (SiO_2) mg/l	3.3	3.0	2.4
Sulphate (SO_4) mg/l	0.0	2.0	5.
Calcium (Ca) mg/l	1[illegible].3	11.1	9.8
Hardness Total ($CaCO_3$) mg/l	43.0	40.7	36.6
Alkalinity Total ($CaCO_3$) mg/l	41.7	41.3	39.1
Specific Conductance, micromho/cm	6[illegible].7	95.	22.7
Total Inorganic Carbon (C) mg/l	9.	8.	9.
Total Organic Carbon (C) mg/l	9.	9.	10.
Total Coliform (M.P.N.)	4.	0	4.
Fecal Coliform (M.P.N.)	0.	0.	0.

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #25 CHURCHILL RIVER AT LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES		
	January 30/73	February 19/73	March 27/73
Turbidity	5.6	6.0	3.4
Temperature (Field)°C	32.	—	—
Temperature (Lab)°C	22.	23.4	23.5
Colour	15.	10.	10.
pH	7.8	7.7	7.6
Chloride (Cl) mg/l	0.9	0.9	1.3
Copper (Cu) mg/l	L 0.001	L 0.002	L 0.003
Fluoride (F) mg/l	0.11	0.20	0.09
Iron (Fe) mg/l	0.03	0.03	0.03
Lead (Pb) mg/l	L 0.002	L 0.003	L 0.004
Manganese (Mn) mg/l	L 0.010	L 0.004	L 0.003
Nitrogen T. Kjeldahl (N) mg/l	—	—	0.31
Nitrogen Nitrate, Nitrite (N) mg/l	0.25	0.12	0.21
Phosphorus Total (P) mg/l	0.015	0.029	0.013
Phosphorus Ortho (P) mg/l	0.005	0.004	0.004
Inorganic Phosphorus (P) mg/l	0.006	0.004	0.003
Potassium (K) mg/l	1.2	1.1	1.1
Non Filterable Residue, mg/l	—	3.6	—
Fixed Residue, mg/l	—	L 0.1	—
Mercury (Hg) µg/l	0.26	0.06	0.36
Zinc (Zn) mg/l	0.002	L 0.002	L 0.002
Sodium (Na) mg/l	3.0	2.6	2.4
Silica (SiO_2) mg/l	2.8	3.0	2.7
Sulphate (SO_4) mg/l	3.2	2.3	2.3
Calcium (Ca) mg/l	11.2	12.5	9.1
Hardness Total ($CaCO_3$) mg/l	42.3	39.5	34.2
Alkalinity Total ($CaCO_3$) mg/l	40.2	38.4	33.6
Specific Conductance, micromho/cm	88.0	84.	69.8
Total Inorganic Carbon (C) mg/l	11.	10.	9.
Total Organic Carbon (C) mg/l	8.	9.	6.
Total Coliform (M.P.N.)	0	0	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #25 CHURCHILL RIVER AT LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES May 1/73	May 17/73	July 3/73
Turbidity	2.2	2.0	
Temperature (Field) °C	—	—	
Temperature (Lab) °C	23.2	24.8	
Colour	15.	10.	
pH	7.7	7.6	
Chloride (Cl) mg/l	1.2	0.7	
Copper (Cu) mg/l	0.002	0.003	
Fluoride (F) mg/l	0.03	0.07	
Iron (Fe) mg/l	L 0.04	L 0.08	
Lead (Pb) mg/l	0.003	L 0.005	
Manganese (Mn) mg/l	L 0.008	L 0.008	
Nitrogen T. Kjeldahl (N) mg/l	—	0.38	
Nitrogen Nitrate, Nitrite (N) mg/l	0.09	0.05	
Phosphorus Total (P) mg/l	0.014	—	
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	
Potassium (K) mg/l	0.9	1.0	
Non Filterable Residue, mg/l	—	—	
Fixed Residue, mg/l	—	—	
Mercury (Hg) µg/l	L 0.02	0.04	
Zinc (Zn) mg/l	0.003	L 0.001	
Sodium (Na) mg/l	2.5	2.5	
Silica (SiO_2) mg/l	3.1	3.2	
Sulphate (SO_4) mg/l	3.4	6.4	
Calcium (Ca) mg/l	10.2	10.5	
Hardness Total ($CaCO_3$) mg/l	32.6	34.0	
Alkalinity Total ($CaCO_3$) mg/l	32.6	32.1	
Specific Conductance, micromho/cm	74.9	80.	
Total Inorganic Carbon (C) mg/l	7.0	6.	
Total Organic Carbon (C) mg/l	7.0	7.	
Total Coliform (M.P.N.)	0.	75.	L 240
Fecal Coliform (M.P.N.)	0.	0	—

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 25 CHURCHILL RIVER AT LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES October 15/73	December 17/73	February 18/74
Turbidity	3.3	4.5	2.2
Temperature (Field) °C	—	—	0.0
Temperature (Lab) °C	18.8	22.0	16.8
Colour	20.	15.	15.
pH	7.6	7.5	7.5
Chloride (Cl) mg/l	1.7	1.6	1.9
Copper (Cu) mg/l	L 0.001	0.003	L 0.001
Fluoride (F) mg/l	0.07	0.10	0.10
Iron (Fe) mg/l	L 0.04	0.06	L 0.04
Lead (Pb) mg/l	L 0.006	L 0.004	L 0.003
Manganese (Mn) mg/l	L 0.008	0.012	L 0.02
Nitrogen T. Kjeldahl (N) mg/l	0.3	0.4	0.7
Nitrogen Nitrate, Nitrite (N) mg/l	0.06	0.09	0.18
Phosphorus Total (P) mg/l	0.009	0.015	0.013
Phosphorus Ortho (P) mg/l	L 0.003	L 0.003	L 0.003
Inorganic Phosphorus (P) mg/l	L 0.003	L 0.003	L 0.003
Potassium (K) mg/l	1.3	1.2	1.2
Non Filterable Residue, mg/l	—	—	—
Fixed Residue, mg/l	—	—	—
Mercury (Hg) µg/l	L 0.04	—	0.06
Zinc (Zn) mg/l	0.001	0.002	L 0.002
Sodium (Na) mg/l	3.3	3.4	3.7
Silica (SiO_2) mg/l	3.4	1.7	2.0
Sulphate (SO_4) mg/l	1.1	3.7	3.4
Calcium (Ca) mg/l	12.	13.	13.
Hardness Total ($CaCO_3$) mg/l	47.	53.	49.
Alkalinity Total ($CaCO_3$) mg/l	45.	50.	49.
Specific Conductance, micromho/cm	98.	110.	110.
Total Inorganic Carbon (C) mg/l	10.	11.	11.
Total Organic Carbon (C) mg/l	4.	9.	8.
Total Coliform (M.P.N.)	0.	L240.	0
Fecal Coliform (M.P.N.)	0	—	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION#25 CHURCHILL RIVER AT LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES April 2, 1974	June 26, 1974	
Turbidity	1.7	3.6	
Temperature (Field)°C	0.0		
Temperature (Lab)°C	13.3	21.5	
Colour	15.	30.	
pH	7.3	7.5	
Chloride (Cl) mg/l	0.7	1.0	
Copper (Cu) mg/l	—	0.002	
Fluoride (F) mg/l	L0.05	0.08	
Iron (Fe) mg/l	—	0.040	
Lead (Pb) mg/l	—	L0.004	
Manganese (Mn) mg/l	—	L0.010	
Nitrogen T. Kjeldahl (N) mg/l	0.5	0.4	
Nitrogen Nitrate, Nitrite (N) mg/l	0.11	0.07	
Phosphorus Total (P) mg/l	0.009	0.015	
Phosphorus Ortho (P) mg/l	--	L0.003	
Inorganic Phosphorus (P) mg/l	—	0.003	
Potassium (K) mg/l	0.7	1.0	
Non Filterable Residue, mg/l	—	i.s.	
Fixed Residue, mg/l	—	i.s.	
Mercury (Hg) ug/l	—		
Zinc (Zn) mg/l	—	0.003	
Sodium (Na) mg/l	1.6	3.0	
Silica (SiO_2) mg/l	2.2	2.7	
Sulphate (SO_4) mg/l	2.3	3.5	
Calcium (Ca) mg/l	8.7	9.7	
Hardness Total ($CaCO_3$) mg/l	29.	38.	
Alkalinity Total ($CaCO_3$) mg/l	26.	36.	
Specific Conductance, micromho/cm	61.	96.7	
Total Inorganic Carbon (C) mg/l	9.	9.	
Total Organic Carbon (C) mg/l	8.	8.	
Total Coliform (M.P.N.)	L240.		
Fecal Coliform (M.P.N.)			

LEGEND MPN = Most probable number per 100 ml

L = Less than

i.s. = insufficient sample

STATION#25 - CHURCHILL RIVER @ LEAF RAPIDS

CONSTITUENTS	SAMPLING DATES July 23, 197[illegible]		
Turbidity	2.		
Temperature (Field) °C	19.4		
Temperature (Lab) °C	21.9		
Colour	5.		
pH	7.4		
Chloride (Cl) mg/l	1.4		
Copper (Cu) mg/l	.002		
Fluoride (F) mg/l	.07		
Iron (Fe) mg/l	L.04		
Lead (Pb) mg/l	.006		
Manganese (Mn) mg/l	.012		
Nitrogen T. Kjeldahl (N) mg/l	.4		
Nitrogen Nitrate, Nitrite (N) mg/l	.05		
Phosphorus Total (P) mg/l	.008		
Phosphorus Ortho (P) mg/l	L.003		
Inorganic Phosphorus (P) mg/l	L.003		
Potassium (K) mg/l	1.3		
Non Filterable Residue, mg/l	--		
Fixed Residue, mg/l	—		
Mercury (Hg) microgram/l	L.05		
Zinc (Zn) mg/l	.003		
Sodium (Na) mg/l	3.5		
Silica (SiO_2) mg/l	2.4		
Sulphate (SO_4) mg/l	3.		
Calcium (Ca) mg/l	32.		
Hardness Total ($CaCO_3$) mg/l	46.		
Alkalinity Total ($CaCO_3$) mg/l	46.		
Specific Conductance, micromho/cm	102.		
Total Inorganic Carbon (C) mg/l	10.		
Total Organic Carbon (C) mg/l	10.		
Total Coliform (M.P.N.)	4.		
Fecal Coliform (M.P.N.)	0.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data

STATION # 26 Lower Churchill River
South Indian Lake

CONSTITUENTS	SAMPLING DATES Sept. 12/72	Oct. 10/72**	Nov. 3/72
Turbidity	5.1	6.6	4.7
Temperature (Field)°C	-	-	-
Temperature (Lab)°C	22.2	22.6	22.0
Colour	10	10	10
pH	8.1	7.9	8.0
Chloride (Cl) mg/l	0.6	-	1.1
Copper (Cu) mg/l	0.002	L0.002	0.002
Fluoride (F) mg/l	0.07	-	0.07
Iron (Fe) mg/l	-	L0.04	L0.04
Lead (Pb) mg/l	L0.006	L0.008	L0.005
Manganese (Mn) mg/l	L0.008	L0.008	L0.0[illegible]
Nitrogen T. Kjeldaal (N) mg/l	0.74	0.55	0.75
Nitrogen Nitrate, Nitrite (N) mg/l	0.92	0.33	0.98
Phosphorus Total (P) mg/l	0.016	0.020	0.015
Phosphorus Ortho (P) mg/l	0.004	L0.003	0.004
Inorganic Phosphorus (P) mg/l	0.004	-	0.004
Potassium (K) mg/l	0.9	L0.1	1.3
Non Filterable Residue, mg/l	5.0	0.1	L0.1
Fixed Residue, mg/l	2.5	2.1*	L0.1
Mercury (Hg) µg/l	0.18	0.001	2.2*
Zinc (Zn) mg/l	0.013	-	-
Sodium (Na) mg/l	1.9	-	2.7
Silica (SiO_2) mg/l	2.8	-	2.6
Sulphate (SO_4) mg/l	0.32		-
Calcium (Ca) mg/l	18.1	20.1	20.7
Hardness Total ($CaCO_3$) mg/l	54.3	69.8	74.3
Alkalinity Total ($CaCO_3$) mg/l	54.6	64.3	66.7
Specific Conductance, micromho/cm	117	134	140
Total Inorganic Carbon (C) mg/l	8	13	14
Total Organic Carbon (C) mg/l	12	7	10
Total Coliform (M.P.N.)	1100	21	0
Fecal Coliform (M.P.N.)	43	4	0

LEGEND MPN = Most probable number per 100 ml

L = Less than
* = sample contaminated
** = insufficient sample to complete analysis

STATION # 26 Lower Churchill River
South Indian Lake

CONSTITUENTS	SAMPLING DATES Dec. 11/72	Jan 30/73	Mar. 1/73
Turbidity	5.3	12	6.3
Temperature (Field) °C	-	-	-
Temperature (Lab) °C	23	22	24.0
Colour	20	20	15
pH	7.8	7.7	7.8
Chloride (Cl) mg/l	2.7	1.1	1.2
Copper (Cu) mg/l	0.004	0.002	0.002
Fluoride (F) mg/l	0.07	0.11	0.09
Iron (Fe) mg/l	L0.01	0.02	0.10
Lead (Pb) mg/l	0.005	L0.002	-
Manganese (Mn) mg/l	L0.005	L0.010	0.065
Nitrogen T. Kjeldahl (N) mg/l	1.52	-	0.46
Nitrogen Nitrate, Nitrite (N) mg/l	0.28	0.18	0.15
Phosphorus Total (P) mg/l	0.034	0	0.014
Phosphorus Ortho (P) mg/l	0.003	0.004	L0.002
Inorganic Phosphorus (P) mg/l	0.003	0.006	L0.002
Potassium (K) mg/l	2.0	1.3	1.3
Non Filterable Residue, mg/l	6.4	-	-
Fixed Residue, mg/l	3.2	-	-
Mercury (Hg) µg/l	0.18	0.05	0.10
Zinc (Zn) mg/l	0.011	0.003	0.010
Sodium (Na) mg/l	4.0	3.6	3.1
Silica (SiO_2) mg/l	3.0	4.2	3.4
Sulphate (SO_4) mg/l	5.5	4.2	3.2
Calcium (Ca) mg/l	19.3	13.8	16.0
Hardness Total ($CaCO_3$) mg/l	54.4	52.8	55.1
Alkalinity Total ($CaCO_3$) mg/l	54.4	52.0	53.7
Specific Conductance, micromho/cm	131	110	111
Total Inorganic Carbon (C) mg/l	12	13	13
Total Organic Carbon (C) mg/l	12	10	9
Total Coliform (M.P.N.)	0	15	0
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION # 26 Lower Churchill River
South Indian Lake

CONSTITUENTS	SAMPLING DATES		
	Mar. 27/73	May 14/73	July 11/73
Turbidity	4.0	2.6	3.8
Temperature (Field) °C	0	-	-
Temperature (Lab) °C	23.5	27.0	24.8
Colour	15	15	0
pH	7.9	7.6	8.2
Chloride (Cl) mg/l	1.1	0.9	0.7
Copper (Cu) mg/l	0.007	L0.003	0.003
Fluoride (F) mg/l	0.08	0.09	0.05
Iron (Fe) mg/l	0.04	0.04	0.07
Lead (Pb) mg/l	L0.004	L0.002	0.004
Manganese (Mn) mg/l	L0.008	L0.006	0.009
Nitrogen T. Kjeldahl (N) mg/l	-	0.27	0.39
Nitrogen Nitrate, Nitrite (N) mg/l	0.47	0.11	0.30
Phosphorus Total (P) mg/l	0.013	0.018	0.012
Phosphorus Ortho (P) mg/l	0.006	0.008	0.003
Inorganic Phosphorus (P) mg/l	0.006	0.008	0.003
Potassium (K) mg/l	1.2	1.1	1.0
Non Filterable Residue, mg/l	-	-	-
Fixed Residue, mg/l	-	-	-
Mercury (Hg) µg/l	I0.05	0.10	0.04
Zinc (Zn) mg/l	0.37	L0.001	0.001
Sodium (Na) mg/l	2.7	2.8	2.3
Silica (SiO_2) mg/l	4.0	3.0	2.8
Sulphate (SO_4) mg/l	2.9	2.4	2.7
Calcium (Ca) mg/l	20.2	12.4	20
Hardness Total ($CaCO_3$) mg/l	58.6	42.7	62
Alkalinity Total ($CaCO_3$) mg/l	55.7	40.1	61
Specific Conductance, micromho/cm	122	96	127
Total Inorganic Carbon (C) mg/l	12	9	12
Total Organic Carbon (C) mg/l	7	10	8
Total Coliform (M.P.N.)	0	240	9
Fecal Coliform (M.P.N.)	0	0	0

LEGEND MPN = Most probable number per 100 ml

L = Less than

STATION #26 Lower Churchill River
South Indian Lake

CONSTITUENTS	SAMPLING DATES Sept. 10/73	Oct. 15/73	
Turbidity	3.3	3.2	
Temperature (Field) °C	-	-	
Temperature (Lab) °C	21.8	17.7	
Colour	15	20	
pH	7.8	7.5	
Chloride (Cl) mg/l	1.2	1.4	
Copper (Cu) mg/l	L0.001	L0.001	
Fluoride (F) mg/l	0.08	0.08	
Iron (Fe) mg/l	L0.02	L0.04	
Lead (Pb) mg/l	L0.005	L0.006	
Manganese (Mn) mg/l	L0.009	L0.008	
Nitrogen T. Kjeldahl (N) mg/l	-	0.3	
Nitrogen Nitrate, Nitrite (N) mg/l	0.02	0.07	
Phosphorus Total (P) mg/l	0.021	0.029	
Phosphorus Ortho (P) mg/l	L0.003	L0.003	
Inorganic Phosphorus (P) mg/l	L0.001	L0.003	
Potassium (K) mg/l	1.0	1.0	
Non Filterable Residue, mg/l	-	-	
Fixed Residue, mg/l	-	-	
Mercury (Hg) µg/l	0.05	-	
Zinc (Zn) mg/l	0.007	L0.001	
Sodium (Na) mg/l	2.2	2.3	
Silica (SiO_2) mg/l	3.4	2.9	
Sulphate (SO_4) mg/l	2.1	1.9	
Calcium (Ca) mg/l	17	15	
Hardness Total ($CaCO_3$) mg/l	52	46	
Alkalinity Total ($CaCO_3$) mg/l	53	44	
Specific Conductance, micromho/cm	103	92	
Total Inorganic Carbon (C) mg/l	12	9	
Total Organic Carbon (C) mg/l	5	8	
Total Coliform (M.P.N.)	23	9	
Fecal Coliform (M.P.N.)	23	4	

LEGEND MPN = Most probable number per 100 ml

L = Less than

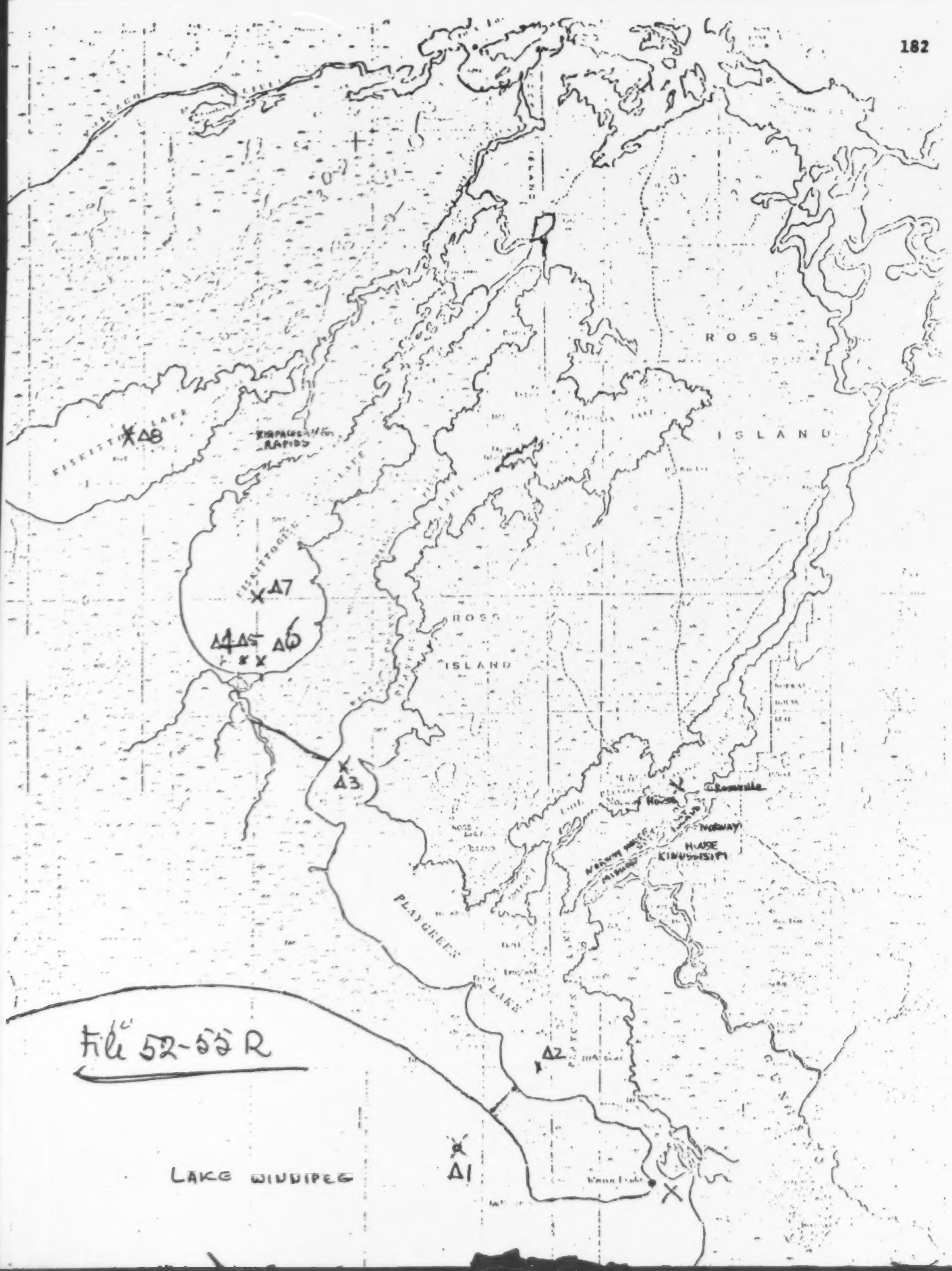
STATION# 26 LOWER CHURCHILL RIVER AT SOUTHERN INDIAN LAKE

CONSTITUENTS	SAMPLING DATES		
	July 27, 1974		
Turbidity	1.5		
Temperature (Field)°C	21.1		
Temperature (Lab)°C	21.8		
Colour	L5.		
pH	7.6		
Chloride (Cl) mg/l	1.		
Copper (Cu) mg/l	L.001		
Fluoride (F) mg/l	.07		
Iron (Fe) mg/l	.13		
Lead (Pb) mg/l	.006		
Manganese (Mn) mg/l	.01		
Nitrogen T. Kjeldahl (N) mg/l	.4		
Nitrogen Nitrate, Nitrite (N) mg/l	.25		
Phosphorus Total (P) mg/l	.004		
Phosphorus Ortho (P) mg/l	L.003		
Inorganic Phosphorus (P) mg/l	L.003		
Potassium (K) mg/l	1.1		
Non Filterable Residue, mg/l	—		
Fixed Residue, mg/l	—		
Mercury (Hg) microgram/l	.12		
Zinc (Zn) mg/l	.003		
Sodium (Na) mg/l	2.8		
Silica (SiO_2) mg/l	2.3		
Sulphate (SO_4) mg/l	2.3		
Calcium (Ca) mg/l	20.		
Hardness Total ($CaCO_3$) mg/l	60.		
Alkalinity Total ($CaCO_3$) mg/l	57.		
Specific Conductance, micromho/cm	124.		
Total Inorganic Carbon (C) mg/l	13.		
Total Organic Carbon (C) mg/l	8.		
Total Coliform (M.P.N.)	23.		
Fecal Coliform (M.P.N.)	4.		

LEGEND MPN = Most probable number per 100 ml

L = Less than

* = Acid contaminated, disregard this data



File 52-53 R

SURVEY: Outlet Lakes: Kiskitto, Kiskittogisu, Playgreen, and Lake Winnipeg
SAMPLES TAKEN: August 27, 1973

Constituents	L. Win. Δ1	Playgreen Δ3	Δ2	Δ4	Δ5	Δ6	Δ7	Kiskitto Δ8
Water Temperature °F	(Not Taken)	67°F	73°F	71°F	70°F	70°F	70°F	70°F
Specific Conductance								
T. O. C.								
T. I. C.								
Total Alkalinity								
Bicarbonate Alkalinity								
Carb. Alkalinity								
Total Hardness								
pH								
D. O.								
B. O. D.								
Residue Unfiltered								
Residue Filter								
Residue Total								
Residue Fixed Non-Filter	19.	10.	10.	10.	10.	12.5	10.	80.
Residue Volatile Non-Filter	.56	.55	.47	.42	.46	.42	.29	.37
Total Phosphate								
Ortho Phosphate								
Total Nitrogen K								
Ammonia								
Nitrate								
Nitrite								
Sulphate								
Chloride								
Sodium								
Calcium								
Magnesium								
Manganese								
Iron								
Total Coliform								
Fecal Coliform								
% Oxygen								
C. O. D.								
Hydroxide								
Lead								
Copper								
Cadmium								
Zinc								
Mercury								

LEGEND: T. O. C. - Total Organic Carbon
T. I. C. - Total Inorganic Carbon
D. O. - Dissolved Oxygen
T. K. N. - Total Nitrogen K
Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4

SURVEY: Outlet Lakes: Kiskitto, Kiskittogisu Playgreen and Lake Winnipeg
SAMPLES TAKEN: July 10/73

Analysis Performed at the Environmental Protection Laboratory

CONSTITUENTS		STATION IDENTIFICATION Δ1	Δ2	Δ3	Δ4	Δ5	Δ6	Δ7	Δ8
Water Temp. °C			18.5	19.	19.5	20.	20.5		20.5
Specific Conductance			280.	280.	274.	277.	255.		259.
T.O.C.			NA	NA	NA	NA	NA		NA
T.I.C.			NA	NA	NA	NA	NA		NA
Total Alkalinity			97.8	96.0	91.6	93.	92.0		92.0
Bicarbonate Alk.			119.	117.	112.	113.	112.		112.
Carbonate Alk.			0	0	0	0	0		0
Total Hardness			163.	161.	157.	157.	145.		145.
pH			8.09	8.12	8.26	8.25	7.21		7.40
DO			8.4	8.6	8.7	8.8	7.5		8.5
B.O.D.			1.4	1.1	1.3	1.7	1.3		1.0
Residue Non Filter			1.	2.	5.	10.	4.		5.
Residue Filter			175.	175.	175.	190.	210.		210.
Residue Total			180.	180.	180.	200.	250.		220.
Residue Fixed Non Filter		—	—	L 5.	L 5.	30.		—	
Residue Volatile Non Filter		—	—	—	—	—		—	
Total Phosphate			0.05	L 0.05	L 0.05	L 0.05	0.20		0.20
Orto Phosphate					L 0.05	L 0.05	0.15		0.04
Total Nitrogen K					L 0.5	L 0.5			0.5
Ammonia			.07	.05	L .05	.06	.05		1.04
Nitrate					.25		.25		.25
Nitrite			.13	.18	.005	L .005	L .005		
Sulphate		30.	28.	30.	28.	37.			27.
Chloride		15.	15.	15.	13.	16.			15.
Sodium		10.	19.	14.	12.	11.	—		14.
Calcium		—	—	—	—	—	—	—	—
Magnesium		—	—	—	—	—	—	—	—
Potassium		2.8	2.4	2.4	2.	2.5			1.4
Iron		.05	L .05	L .05	12.5	.4			0.4
Total Coliform		0	0	0	7	9			4
Fecal Coliform		0	0	0	2	2			0
Copper		.1	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01		L 0.01
Lead		.1	0.01	L 0.01	0.01	L .01			L 0.01
Manganese		L .05	L .05	L .05	L .05	.1			L .05
Zinc		.1	0.03	0.04	0.03	0.02			0.01
Silica		L 2.	L 2.	L 2.	4.1	4.1			4.
Fluoride		L .1	.1	L .1	L .1	.19			.16
Mercury		0.0001	L0.0001	.0001	0.0001	.0002			.0006

LEGEND:- T.O.C. - Total Organic Carbon
T.I.C. - Total Inorganic Carbon
D.O. - Dissolved Oxygen
B.O.D. - Biochemical Oxygen Demand
Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4
T.K.N. - Total Nitrogen Kjeldhal

SURVEY: Outlet Lakes: Kiskitto, Kiskittogisu, Playgreen and Lake Winnipeg
SAMPLES TAKEN: June 12/73

Analysis Performed at the Environmental Protection Laboratory

	STATION IDENTIFICATION							
CONSTITUENTS	Δ1	Δ2	Δ3	Δ4	Δ5	Δ6	Δ7	Δ8
Water Temp. °C	9.0	8.5	10.	11.5	11.5	1 .0	12.5	12.
Specific Conductance	10.	30.	314.	2[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]
T.O.C.	10.	13.	4[illegible]	[illegible]	[illegible]	[illegible]	13.	[illegible]
T.I.C.	17.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Alkalinity	89.0	87.	[illegible]	[illegible]	87.2	[illegible]	[illegible]	[illegible]
Bicarbonate Alk.	109.0	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Carbonate Alk.	0	0	[illegible]	0	0	0	0	0
Total Hardness	120.	118.	[illegible]	[illegible]	112.	[illegible]	47.	[illegible]
pH	8.04	8.11	7.97	[illegible]	7.91	[illegible]	8.[illegible]	[illegible]
DO	—	—	—	—	—	—	—	—
B.O.D.	—	—	—	—	—	—	—	—
Residue Non. Filter	10.	L 5.	10.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Residue Filter	190.	175.	180.	[illegible]	[illegible]	170.	[illegible]	[illegible]
Residue Total	—	—	—	—	—	—	—	—
Residue Fixed Non Filter	—	—	—	—	—	—	—	—
Residue Volatile Non Filter	—	—	—	—	—	—	—	—
Total Phosphate	L 0.05	L 0.05	L 0.05	0.05	0.05	0.05	L 0.05	0.70
Ortho Phosphate	—	—	—	—	—	—	—	—
Total Nitrogen KJELDHAL	L .5	L .5	.5	L .5	L .5	L .5	L .[illegible]	.7
Ammonia	L .05	L .05	.05	.07	.07	L .05	L .[illegible]	[illegible]
Nitrate	.25	L .1	.[illegible]	.[illegible]	[illegible]	[illegible]	.4	.[illegible]
Nitrite	L .[illegible]	L .[illegible]	L .[illegible]	L .[illegible]	.[illegible]	L .[illegible]	.[illegible]	[illegible]
Sulphate	33.	32.	32.	43.	[illegible]	45.	[illegible]	[illegible]
Chloride	17.	17.	17.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sodium	16.	16.	16.	[illegible]	[illegible]	13.	[illegible]	[illegible]
Calcium	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	—	—	—	—	—	—	—	—
Potassium	—	—	—	—	—	—	—	—
Iron	0.05	L 0.05	0.05	[illegible]	[illegible]	[illegible]	L [illegible]	[illegible]
Total Coliform	4.	7.	0	[illegible]	[illegible]	[illegible]	0	0
Fecal Coliform	0	2.	—	2.	2.	4.	—	—
Copper	L 0.01	L 0.01	L 0.01	L [illegible]	L [illegible]	L [illegible]	L [illegible]	L [illegible]
Lead	0.01	0.01	[illegible]	[illegible]	L [illegible]	L 0.01	L 0.01	L 0.01
Silica	[illegible]	—	—	—	—	—	—	[illegible]
Cadmium	—	0.01	—	[illegible]	L [illegible]	L [illegible]	L [illegible]	L [illegible]
Zinc	L 0.01	0.01	0.01	L [illegible]	[illegible]	[illegible]	0.01	L [illegible]
Colour True	5.	L 5.	10.	[illegible]	[illegible]	5.	5.	15.
Turbidity	L .5	L[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluoride	.14	.13	.13	[illegible]	.[illegible]	.[illegible]	.17	[illegible]
Manganese	L .05	L .05	L .05	L .05	L .05	L .05	L .05	—

LEGEND:- T.O.C. - Total Organic Carbon
T.I.C. - Total Inorganic Carbon
D.O. - Dissolved Oxygen
B.O.D. - Biochemical Oxygen Demand
Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4
T.K.N. - Total Nitrogen Kjeldhal

SURVEY: Outlet Lakes: Kiskitto, Kis[illegible]agisu, Playgreen and Lake Winnipeg
SAMPLES TAKEN: March 13/73

Analysis Performed at the Environmental Protection Laboratory

CONSTITUENTS	STATION IDENTIFICATION							
	Δ1	Δ2	Δ3	Δ4	Δ5	Δ6	Δ7	Δ8
Water Temp. °C	0°	0	0	0	0	0	0	0
Specific Cond.	381.	381.	378.	490.	517.	530.	391.	503.
T.O.C.	10.0	10.5	9.0	14.0	15.0	23.5	10.5	16.5
T.I.C	32.5	32.0	31.0	40.5	44.0	40.5	28.0	38.5
Total Alkalinity	33.	1[illegible].	12[illegible].	17[illegible].	1[illegible].	17[illegible].	1[illegible].	1[illegible].
Bicarbonate Alk.	1.0.	1[illegible].	1[illegible].	1[illegible]	2[illegible].	.17.	1[illegible].	[illegible].
Carbonate Alk.	4.8	0.0	0.0	0.0	4.[illegible]	0.0	0.0	0.0
Total Hardness	<35.	3[illegible].	120.	[illegible].	[illegible].	210.	1[illegible].	1[illegible].
pH	8.34	8.15	8.05	8.[illegible]5	8.30	8.12	8.18	8.24
D.O.	—	—	—	—	—	—	—	—
B.O.D.	—	—	—	—	—	—	—	—
Residue Non Filter	—	—	—	—	—	—	—	—
Residue Filter	—	—	—	—	—	—	—	—
Residue Total	170.	160.	160.	[illegible]10.	[illegible].	[illegible]50.	1[illegible].	[illegible]30.
Residue Fixed Non Filter	—	—	—	—	—	—	—	—
Residue Volatile Non Filter	—	—	—	—	—	—	—	—
Total [illegible]	.1[illegible]	0.09	0.09	0.1[illegible]	0.[illegible]	0.1[illegible]	[illegible].05	0.07
Ortho [illegible]	—	—	—	—	—	—	—	—
[illegible]	—	—	—	—	—	—	—	—
Ammonia	—	—	—	—	—	—	—	—
Nitrate	.20	.10	.[illegible]5	.[illegible]15	[illegible].10	.[illegible]32	.[illegible]30	.[illegible]3
Nitrite	L .005	L .005	L .005	L .00[illegible]	L .00[illegible]5	L .0[illegible]5	L .005	L .005
Sulphate	39.	36.	35.	4[illegible].	4[illegible].	[illegible]2.	37.	33.
Chloride	[illegible].	21.	19.	[illegible]2.	[illegible]3.	33.	2[illegible]	[illegible]5
Sodium	[illegible].	2.6	17.	[illegible]3.	2[illegible].	47.	30.	2[illegible]
Calcium	—	—	—	—	—	—	—	—
Magnesium	—	—	—	—	—	—	—	—
Potassium	3.2	15.	2.6	4.4	[illegible]4.7	4.7	3.2	3.2
Iron	.95	.78	.35	.55	1.[illegible]2	.[illegible]76	.15	.52
Total Coliform	0	39.	4.	0	4.	4[illegible].	0	0
Fecal Coliform	0	0	0	0	0	0	0	0
Colour True	10.	10.	10.	15.	[illegible]0.	[illegible]0.	15.	10.
Turbidity	10.	11.	10.	15.	[illegible]0.	1[illegible].	1[illegible]	35.
Manganese	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05
Copper	.01	.01	L .01	[illegible].01	[illegible].01	[illegible].01	L .01	[illegible].01
Lead	.01	.01	[illegible].01	[illegible].01	[illegible].02	[illegible].01	.01	[illegible].01
[illegible]ide	.14	.14	[illegible].14	[illegible].14	[illegible].19	[illegible].16	.13	[illegible].10
Ammonia	.07	.07	[illegible].04	[illegible].0[illegible]	[illegible].12	[illegible].10	[illegible].09	[illegible].13
Zinc	.04	.02	[illegible].0[illegible]	[illegible].[illegible]2	[illegible].02	.01	[illegible].02	[illegible].03
T.K.N.	.6	.6	L .5	.6	.7	.7	.5	.7
Silica	1.0	—	—	—	—	—	—	—
Mercury (Hg)	.0001	.0002	.0001	[illegible].0001	[illegible].0004	—	—	—

LEGEND:- T.O.C. - Total Organic Carbon
T.I.C. - Total Inorganic Carbon
D.O. - Dissolved Oxygen
B.O.D. - Biochemical Oxygen Demand
Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4
T.K.N. - Total Nitrogen Kjeldhal

Survey Outlet Lakes: Kiskitto, Kiskittogisu, Playgreen's Lakes Winnipeg

Samples Taken: February 27, 1974
Analysis Performed at the Environmental Protection Laboratory

Constituents	Station Identification					
	Δ1	Δ2	Δ3	Δ4	Δ5	Δ6
Water Temperature °C						
Specific Conductance	340.	330.	330.	330.	330.	
T.O.C.	NA	NA	NA	NA	NA	
T.I.C.	NA	NA	NA	NA	NA	
Total Alkalinity	117.	117.	116.	130.	130.	
Bicarbonate Alkalinity	143.	143.	142.	134.	218.	134.
Carbonate Alkalinity	0.0	0	0	0	0	0
Total Hardness	142.	147.	151.	150.	220.	150.
pH	8.2	8.0	8.0	7.92	8.01	8.2
D.O.	12.	10.6	TAKEN			
B.O.D.						
Residue Non-Filter	10.	2.	5.	2.	15	2.
Residue Filter	230.	240.	270.	230.	313.	230.
Residue Total	240.	250.	270.	230.	320.	230.
Residue Fixed Non-Filter						
Residue Volatile Non-Filter						
Total Phosphate	0.11	0.15	0.05	0.08	0.07	0.04
Ortho Phosphate						
Total Nitrogen K	0.7	0.6	0.7	0.6	0.8	0.5
Ammonia	0.07	0.07	0.12	0.20	0.12	0.09
Nitrate	0.02	0.03	0.08	0.06	0.02	0.01
Nitrite						
Sulphate	44.	42.	42.	34.	68.	43.
Chloride	24.	23.	22.	22.	32.	24.
Sodium	21.	20.	23.	20.	45.	21.
Calcium						
Magnesium	22.	19.	23.	19.	22.	23.
Potassium	3.0	3.0	3.0	3.0	3.0	3.0
Iron	L 0.05	L 0.05	0.05	L 0.05	0.13	0.07
Total Coliform	8	9	4	0	23.	3.
Fecal Coliform	0	0	0	0	0	0
% Oxygen						
C.O.D.						
Hydroxide						
Lead	0.01	0.01	0.01	0.01	0.01	0.01
Copper	0.01	0.02	0.01	0.01	0.01	0.01
Cadmium						
Zinc	0.02	0.03	0.06	0.03	0.04	0.02
Nickel						
Colour True	10.	5.	5.	7.	10.	10.
Turbidity	7.	7.	9.	7.	10.	10.
Manganese	L .02	L .02	0.02	L .02	L .02	L 0.02
Silica						
Fluoride	.16	.14	.13	.14	.15	.12

LEGEND: T.O.C. - Total Organic Carbon; D.O. - Dissolved Oxygen
T.I.C. - Total Inorganic Carbon
Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4
T.K.N. - Total Nitrogen Kjeldhal; B.O.D. - Biochemical Oxygen Demand

SURVEY OUTLET LAKES: Kiskitto, Kiskittegisu, Playgreen and Lake Winnipeg

SAMPLES TAKEN: October 19, 1973

Constituents	1	2	3	4	5	6	7	8
Water Temperature °C	6.5	4.0	5.5	3.0	3.0	3.0	4.0	3.0
Specific Conductance	295.	400.	295.	295.	295.	290.	290.	240.
T.O.C.	9.0	10.5	10.5	20.	9.5	10.5	10.5	18.0
T.I.C.	NA	NA	NA	NA	NA	NA	NA	NA
Total Alkalinity	98.4	104.	103.	100.	106.	110.	104.	101.
Bicarbonate Alkalinity	120.	127.	125.	120.	129.	134.	127.	123.
Carbonate Alkalinity	0	0	0	0.0	0	0	0	0
Total Hardness	143.	143.	140.	150.	143.	140.	150.	133.
pH	8.11	7.91	8.0	8.01	7.98	7.97	8.10	8.00
D.O.	11.6	11.8	11.9	11.2	12.5	11.4	12.0	11.0
B.O.D.	1.6	1.8	2.1	0.0	2.2	1.7	1.6	0.9
Residue Non-Filter	15.	80.	15.	20.	15.	25.	40.	135.
Residue Filter		150.	155.	165.	155.	145.	160.	145.
Residue Total	170.							
Residue Fixed Non-Filter	155.							
Residue Volatile Non-Filter								
Total Phosphate	L.05	0.09	.05	.06	.06	L.05	0.06	0.14
Ortho Phosphate	0.05	0.07	L0.05	0.08	0.18	0.10	L.05	0.03
Total Nitrogen K	L00.5	L0.5	L0.5	L.5	L0.5	L0.05	L0.05	
Ammonia	L0.05	0.16	L0.05	0.12	0.12	0.12	0.16	NA
Nitrate	L.1	L.1	L.1	L.1	L.1	L.1	L.1	L.1
Nitrite	L.005	L.005	L.005	L.005	L.005	L.005	L.005	L.005
Sulphate	13.	13.	39.	65.	27.	27.	28.	12.
Chloride	17.	20.	17.	15.	18.	15.	15.	19.
Sodium	15.	15.	15.	13.	13.	13.	15.	13.
Calcium	0.0	0	0	0				
Magnesium								
Potassium	3.5	4.	4.	3.5	4.	3.5	4.	4.5
Iron	0.14	0.04	0.01	0.4	0.3	0.46	0.83	2.37
Total Coliform	0	9	4	4	0	0	0	0
Fecal Coliform	0	0	0	0	0	0	0	0
% Oxygen	97.8	82.9	97.6	85.0	97.0	95.	94.5	84.2
Lead	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Copper	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01
Cadmium								
Zinc	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nickel								
Colour True	5.	25.	5.	20.	15.	20.	20.	15.
Turbidity	23.	55.	16.	46.	40.	47.	68.	83.
Manganese	0.02	0.04	L0.02	0.02	L0.02	0.02	0.03	0.04
Silica								
Fluoride	.16	.14	.18	.14	.15	.15	.17	.23

Legend - TOC - Total organic carbon
TIC - Total inorganic carbon
DO - Dissolved Oxygen

Total Phosphate and Ortho Phosphate are expressed in mg/l of PO_4

TKN - Total nitrogen Kjeldhel: BOD - Biochemical oxygen demand.

SURVEY: Outlet Lakes: Kiskitto, Kiskittogisu, Playgreen & Lake Winnipeg

SAMPLES TAKEN: September 11, 1973

Constituents	Station Identification							
	Δ1	Δ2	Δ3	Δ4	Δ5	Δ6	Δ7	Δ8
Water Temperature °C	15°	15°	15°	15°	15°	15°	15°	15°
Specific Conductance	300.		300.	295.	300.	290.	295.	290.
T.O.C.	14.		15.5	13.0	19.5	16.	20.	17.
T.I.C.	21.		19.5	21.0	21.0	18.	20.	20.
Total Alkalinity	120.		120.	120.	120.	120.	120.	120.
Bicarbonate Alkalinity	120.		120.	120.	120.	120.	120.	120.
Carbonate Alkalinity	0.		0.	0.	0.	0.	0.	0.
Total Hardness	125.		125.	125.	125.	125.	125.	125.
pH	7.80		7.85	7.74	7.78	7.80	7.85	7.80
D.O.	9.7		9.8	9.4	9.4	9.8	9.8	9.9
B.O.D.	1.3		1.0	0.2	0.8	0.8	0.8	0.7
Residue Non-Filter								
Residue Filter	180.		225.	170.	175.	185.	200.	180.
Residue Total								
Residue Fixed Non-Filter	5.		10.	15.	20.	20.	10.	80.
Residue Volatile Non-Filter	—		—	—	—	—	—	—
Total Phosphate	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ortho Phosphate	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Nitrogen (T.K.N.)	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ammonia	<0.05		<0.05	<0.05	0.05	<0.05	<0.05	<0.05
Nitrate	.2		.2	.2	.2	.2	.2	.4
Nitrite	<.005		<.005	<.005	<.005	<.005	<.005	.005
Sulphate	25.		25.	25.	25.	25.	25.	25.
Chloride	15.		15.	15.	15.	14.	15.	9.
Sodium	12.5		12.5	12.	12.5	12.5	12.5	8.
Calcium	33.		33.	33.	33.	33.	33.	33.
Magnesium	11.		11.	11.	11.	11.	11.	9.
Potassium	2.5		2.5	2.5	2.6	2.5	2.5	2.7
Iron	<0.05		0.07	0.07	0.09	0.15	0.12	0.21
Total Coliform	9.	9.	12.	4.	0.	4.	0.	0.
Fecal Coliform	0.	0.	0.	0.	0.	0.	0.	0.
% Oxygen	100.01		96.5	100.01	100.01	100.00	100.02	97.0
C.O.D.								
Hydroxide	0.		0.	0.	0.	0.	0.	0.
Lead	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.04		<0.1	<0.01	<0.1	<0.1	<0.1	<0.01
Zinc	0.04		0.03	0.03	0.02	0.03	<0.01	0.01
Nickel	0.02		<0.02	<0.02	0.02	<0.02	<0.02	0.02
Colour True	10.		10.	5.	12.	12.	21.	26.
Turbidity	13.5		2.0	1.0	4.0	29.	9.	23.
Manganese	<.025		<.025	<.025	<.025	<.025	<.025	.05
Silica	2.1			2.0				2.1
Fluoride	.19		.18	.18	.19	.19	.19	.18

LEGEND T.O.C. - total organic carbon
T.I.C. - total inorganic carbon
D.O. - dissolved oxygen
Total phosphate and ortho phosphate are expressed in mg/l of PO_4
T.K.N. - total nitrogen kieldhal
B.O.D. - Biochemical Oxygen Demand

OUTLET LAKES SURVEY: Lakes Winnipeg, Playgreen, Kiskittogisu and Kiskitto

SAMPLING DATE: July 24, 1974

CONSTITUENTS	STATION IDENTIFICATION							
	Δ 1	Δ 2	Δ 3	Δ 4	Δ 5	Δ 6	Δ 7	Δ 8
WATER TEMPERATURE AT SAMPLING, °C								
COLOR - TRUE		90.	50.	10.	10.	10.	10.	
TURBIDITY		5.5	15.	9.	6.5	8.5	3.5	
MAGNESIUM (Mg) mg/l		12.	12.	12.	12.	12.	12.	
SODIUM (Na) mg/l		20.	20.	20.	20.	20.	15.	
POTASSIUM (K) mg/l		2.7	3.3	3.	2.9	3.	2.9	
T. HARDNESS ($CaCO_3$) mg/l		113.	150.	135.	160.	155.	125.	
T. PHOSPHATE (PO_4) mg/l		0.07	0.1[illegible]	0.11	0.09	0.10	0.07	
ORTHO PHOSPHATE (PO_4) mg/l		L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	
CHLORIDE (Cl) mg/l		24.5	27.	20.5	29.5	28.	19.	
FLUORIDE (F) mg/l		0.11	0.11	0.1	0.11	[illegible]	0.1[illegible]	
SULPHATE (SO_4) mg/l		29.	34.	24.	25.	26.	24.	
SPECIFIC CONDUCTANCE (micromho/cm)		285.	304.	337.	299.	302.	297.	
TOTAL RESIDUE mg/l		190.	200.	200.	200.	190.	170.	
NON FILTERABLE RESIDUE mg/l		----	----	----	----	----	----	
FILTERABLE RESIDUE mg/l		190.	200.	200.	200.	190.	170.	
T. ORGANIC CARBON (C) mg/l		----	----	----	----	----	----	
T. INORGANIC CARBON (C) mg/l		----	----	----	----	----	----	
FREE AMMONIA (N) mg/l		0.04	L0.02	L0.02	0.05	L0.02	L0.02	
NITRATE - NITRITE (Total N) mg/l		L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	
T. KJELDAHL NITROGEN (N) mg/l		0.3	0.2	0.1	0.3	0.3	0.2	
DISSOLVED OXYGEN mg/l		9.	8.8	9.	9.	8.3	8.9	
PERCENT OXYGEN								
BIOCHEMICAL OXYGEN DEMAND mg/l		0.5	0.5	0.5	0.5	0.6	0.7	
T. ALKALINITY ($CaCO_3$) mg/l		88.	98.	97.	98.	106.	97.	
BICARBONATE ALKALINITY (HCO_3) mg/l		107.	120.	118.	120.	129.	118.	
CARBONATE ALKALINITY (CO_3) mg/l		0.0	0.0	0.0	0.0	0.0	0.0	
HYDROXIDE ALKALINITY (OH) mg/l		0.0	0.0	0.0	0.0	0.0	0.0	
pH		8.10	7.91	8.20	8.25	8.19	8.15	
TOTAL COLIFORM (MPN per 100 ml.)		4.	23.	0.	0.	0.	0.	
FECAL COLIFORM (MPN per 100 ml.)		0.	9.	0.	0.	0.	0.	
CALCIUM (Ca) mg/l		25.	40.	34.	44.	42.	30.	

LEGEND: L = Less Than

OUTLET LAKES SURVEY: LAKES WINNIPEG, PLAYGREEN, KISKITTOGISU, AND KISKITTO

SAMPLING DATE: June 18, 1974

CONSTITUENTS	STATION IDENTIFICATION							
	Δ 1	Δ 2	Δ 3	Δ 4	Δ 5	Δ 6	Δ 7	Δ 8
WATER TEMPERATURE AT SAMPLING, °C	9.4	12.2	10.0	17.2	17.2	17.2	16.7	17.8
COLOR - TRUE	5.	5.	5.	20.	20.	30.	15.	20.
TURBIDITY	5.	9.5	5.	20.	25.	25.	15.	95.
MAGNESIUM (Mg) mg/l	20.	16.	16.	15.	16.	14.	14.	9.0
SODIUM (Na) mg/l	16.	16.	20.	15.	15.	15.	15.	L10.
POTASSIUM (K) mg/l	3.	3.	3.	3.	3.3	3.3	2.7	4.3
T. HARDNESS ($CaCO_3$) mg/l	150.	143.	143.	130.	134.	120.	130.	108.
T. PHOSPHATE (PO_4) mg/l	0.20	0.12	0.20	0.28	0.24	0.17	0.16	0.6
ORTHO PHOSPHATE (PO_4) mg/l	0.06	0.08	0.07	0.20	0.08	0.09	0.08	0.13
CHLORIDE (Cl) mg/l	23.5	23.	24.	15.	15.5	15.	15.5	6.5
FLUORIDE (F) mg/l	----	----	----	----	----	----	----	----
SULPHATE (SO_4) mg/l	23.	25.	29.	26.	24.	24.	22.	30.
SPECIFIC CONDUCTANCE (micromho/cm)	333.	341.	321.	270.	293.	272.	272.	194.
TOTAL RESIDUE mg/l	230.	240.	240.	230.	230.	230.	220.	290.
NON FILTERABLE RESIDUE mg/l	15.	10.	10.	20.	15.	20.	20.	75.
FILTERABLE RESIDUE mg/l	250.	230.	230.	210.	220.	210.	200.	200.
T. ORGANIC CARBON (C) mg/l	11.5	12.5	11.5	9.5	11.	15.5	11.	14.5
T. INORGANIC CARBON (C) mg/l	24.5	24.	24.	21.5	22.	22.5	21.	18.5
FREE AMMONIA (N) mg/l	L0.02	L0.02	L0.02	L0.02	0.03	0.04	0.02	0.06
NITRATE - NITRITE (Total N) mg/l	0.01	0.04	0.02	L0.01	0.21	0.01	0.02	0.04
T. KJELDAHL NITROGEN (N) mg/l	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
DISSOLVED OXYGEN mg/l	12.	12.	11.	9.7	12.	10.	9.3	----
PERCENT OXYGEN	107.							----
BIOCHEMICAL OXYGEN DEMAND mg/l	L0.5	L0.5	0.9	L0.5	L0.5	L0.5	L0.5	L0.5
T. ALKALINITY ($CaCO_3$) mg/l	101.	94.	94.	88.	89.	86.	86.	75.0
BICARBONATE ALKALINITY (HCO_3) mg/l	123.	115.	115.	107.	109.	105.	105.	92.7
CARBONATE ALKALINITY (CO_3) mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROXIDE ALKALINITY (OH) mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pH	7.90	7.95	7.89	7.81	7.95	8.10	8.01	7.71
TOTAL COLIFORM (MPN per 100 ml.)	0.	3.	0.	0.	0.	----	0.	0.
FECAL COLIFORM (MPN per 100 ml.)	0.	0.	0.	0.	0.	----	0.	0.
CALCIUM (Ca) mg/l	27.	32.	31.	27.	27.	25.	29.	28.

LEGEND: L = Less Than

OUTLET LAKES SURVEY: LAKES WINNIPEG, PLAYGREEN, KISKITTOGISU, AND KISKITTO

SAMPLING DATE: September 16, 1974

CONSTITUENTS	STATION IDENTIFICATION							
	Δ 1	Δ 2	Δ 3	Δ 4	Δ 5	Δ 6	Δ 7	Δ 8
WATER TEMPERATURE AT SAMPLING, °C	11.	11.	10.	9.	9.	9.5	10.	9.
COLOR - TRUE	5.	10.	5.	5.	10.	7.	7.	L5.
TURBIDITY	45.	75.	45.	25.	85.	55.	15.	85.
MAGNESIUM (Mg) mg/l	13.	17.	13.	12.	13.	12.	12.	10.
SODIUM (Na) mg/l	17.	17.	17.	17.	17.	17.	17.	10.
POTASSIUM (K) mg/l	3.4	3.7	3.2	3.1	4.	3.7	2.8	2.8
T. HARDNESS ($CaCO_3$) mg/l	145.	170.	148.	134.	146.	137.	132.	121.
T. PHOSPHATE (PO_4) mg/l	0.17	0.24	0.17	0.12	0.21	0.13	0.07	0.19
ORTHO PHOSPHATE (PO_4) mg/l	LO.05	LO.05	LO.05	LO.05	LO.05	LO.05	LO.05	LO.05
CHLORIDE (Cl) mg/l	16.	16.	16.	18.	17.	17.	18.	6.
FLUORIDE (F) mg/l								
SULPHATE (SO_4) mg/l	37.	36.	32.	28.	35.	30.	25.	20.
SPECIFIC CONDUCTANCE (micromho/cm)	350.	346.	348.	329.	335.	338.	333.	317.
TOTAL RESIDUE mg/l	300.	360.	300.	280.	340.	310.	250.	300.
NON FILTERABLE RESIDUE mg/l	25.	50.	50.	30.	70.	50.	10.	50.
FILTERABLE RESIDUE mg/l	320.	310.	250.	250.	270.	260.	240.	250.
T. ORGANIC CARBON (C) mg/l	6.	12.5	8.5	7.5	10.5	7.5	9.	12.
T. INORGANIC CARBON (C) mg/l	21.5	23.	21.5	20.5	21.5	22.	19.	18.5
FREE AMMONIA (N) mg/l	0.02	0.02	0.02	0.02	0.04	0.03	LO.02	LO.02
NITRATE - NITRITE (Total N) mg/l	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
T. KJELDAHL NITROGEN (N) mg/l	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3
DISSOLVED OXYGEN mg/l	9.6	9.8	9.1	9.7	10.	9.3	10.	10.
PERCENT OXYGEN	90.	92.	83.	87.	89.	85.	92.	89.
BIOCHEMICAL OXYGEN DEMAND mg/l	0.8	0.9	0.9	1.2	1.0	1.0	0.9	0.7
T. ALKALINITY ($CaCO_3$) mg/l	116.	121.	124.	116.	117.	104.	109.	104.
BICARBONATE ALKALINITY (HCO_3) mg/l	121.	138.	146.	137.	133.	112.	133.	127.
CARBONATE ALKALINITY (CO_3) mg/l	?	?	2.4	2.4	4.80	?	0.	0.
HYDROXIDE ALKALINITY (OH) mg/l	0.		0.	0.	0.	0.	0.	0.
pH	8.35	8. 35	8.31	8.35	8.39	8.35	8.29	8.19
CALCIUM (Ca) mg/l	36.5	40.	38.	34.	37.	35.	33.	32.
MANGANESE (Mn) mg/l	0.03	0.03	0.05	0.02	LO.02	0.05	0.02	LO.02
IRON (Fe) mg/l	0.3	0.45	0.15	0.13	0.5	0.4	0.1	0.35
ZINC (Zn) mg/l	LO.01	0.02	LO.01	0.01	LO.01	LO.01	LO.01	LO.01
COPPER (Cu) mg/l	LO.01	LO.01	LO.01	LO.01	0.01	LO.01	0.01	LO.01
CADMIUM (Cd) mg/l	LO.01	LO.01	LO.01	LO.01	LO.01	LO.01	LO.01	LO.01
LEAD (Pb) mg/l	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

LEGEND: L = Less Than

APPENDIX 2, VOL. 2 - B
WATER LEVEL AND FLOW INFORMATION

WATER LEVEL AND FLOW INFORMATION

by

Planning Division, Water Resources Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba
March, 1975

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD

SPECIAL NOTE

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED IN THIS APPENDIX ARE THOSE OF THE AUTHOR(S) AND ARE NOT NECESSARILY THE SAME AS THE CONCLUSIONS AND RECOMMENDATIONS OF THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD AS EXPRESSED IN THE SUMMARY REPORT AND THE TECHNICAL REPORT.

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

WATER LEVEL AND FLOW INFORMATION

Two sets of water level and flow information are provided in this report. Both sets have been developed by the Manitoba Water Resources Branch utilizing mean monthly values. One set is based on projections without the Lake Winnipeg Regulation and the Churchill River Diversion projects in place. The other set is based on projections with the two Manitoba Hydro projects in effect. Therefore, the impact of the projects on the water regime can be compared directly.

The information with the regulation and diversion projects in effect was developed from data supplied by Manitoba Hydro. The information without the Manitoba Hydro projects in place was prepared from computations undertaken by the Saskatchewan-Nelson Basin Board (SNBB). This latter information has been termed modified historic data.

Modified historic data are historic data adjusted to account for present day use. In computating modified historic data, it is assumed that all of the developments and water uses that exist in the Churchill and Nelson rivers systems had been in operation over the historic period of record. Therefore, the modified historic data indicates the hydrologic conditions that can be expected to occur in the future provided that no more water use or water manipulating developments take place in the river systems and that the historic hydrologic period is repeated. In most cases, the modified historic data was supplied directly by the SNBB. However, when data was unavailable from the SNBB, it was supplied by Manitoba Hydro. The

modified historic data supplied by Manitoba Hydro was, however, based on information supplied by the SNBB and approved by the Water Resources Branch. The SNBB has since disbanded, however, its data bank is being stored with the Prairie Provinces Water Board in Regina.

Manitoba Hydro in its calculations assumed the same basic conditions as did the SNBB and projected the water level and flow conditions in the Study Area with Lake Winnipeg regulated and up to 30,000 cfs diversion from the Churchill River.

The information provided is separated into the six geographic study areas as defined by the Study Board, Lake Winnipeg, Outlet Lakes, Southern Indian Lake, Diversion Route, Lower Churchill River and Lower Nelson River.

In addition to the information provided in this report, the Water Resources Branch provided specific water level and flow information on request from study participants. This information is contained in the respective working documents prepared by those study participants.

The water level and flow information was continually updated during the course of the study as new information became available. The information presented in this report represents the data that was current at the time of report preparation.

LAKE WINNIPEG AND THE OUTLET LAKES

The water level and flow information for Lake Winnipeg and the Outlet Lakes regions was based on the hydrologic period from November 1927 to November 1966.

The SNBB provided modified historic mean monthly outflow data for Lake Winnipeg and Cross Lake. The modified historic water levels for the two lakes and for the lakes between them were developed by the Water Resources Branch using SNBB outflow data and water level-flow relationships supplied by Manitoba Hydro. The modified historic flow in the East Channel and the West Channel of the Nelson River was also computed by the Water Resources Branch from SNBB Lake Winnipeg outflow information and water level-flow relationship curves supplied by Manitoba Hydro.

For the case with Lake Winnipeg regulated, Manitoba Hydro provided data on Lake Winnipeg and Cross Lake levels, and flows at the outlet of Lake Winnipeg, in the West Channel of the Nelson River and at the outlet of Cross Lake. The data provided by Manitoba Hydro was computed by simulating the utility's sequence of development labelled GIJA. Sequence GIJA incorporates Lake Winnipeg Regulation between elevations 711 and 715 feet beginning in November 1974, and diversion of up to 30,000 cfs from the Churchill River effective November 1975.

Using the Lake Winnipeg levels and corresponding outflows and the water level-flow curves mentioned above, the Water Resources Branch developed level information for Playgreen Lake (north and south end) and Kiskittogisu Lake. The flow in the East Channel under regulation was obtained by subtracting the West Channel flow from total Lake Winnipeg outflow, both of which were provided by Manitoba Hydro.

Kiskitto Lake will be controlled by a dam and the levels could not be computed from information provided. Therefore, the water level information for that lake was provided directly by Manitoba Hydro.

SOUTHERN INDIAN LAKE AND THE DIVERSION ROUTE

The water levels and flows in these two regions will depend on the amount of water to be diverted from the Churchill River to the Nelson River system. The November 1927 to November 1966 hydrologic period was used in developing water level and flow information for these study regions (hereinafter referred to as the hydrologic period 1928 to 1966).

Manitoba Hydro provided modified historic mean monthly inflow, outflow and lake level data for Southern Indian Lake which was based on values received from the SNBB. The SNBB provided mean monthly natural flows at Notigi, and Wuskwatim on the Rat-Burntwood River system. At these two locations natural flows are identical to modified historic flows as there are no developments on either the Rat or Burntwood rivers.

For the condition with the Churchill River Diversion project in operation, Manitoba Hydro supplied mean monthly Southern Indian Lake levels and flows at Notigi and Wuskwatim on the Diversion route.

During November - December, 1974 and January, 1975 Manitoba Hydro supplied additional water level and flow data relative to conditions after diversion. These data were based on obtaining maximum energy from Churchill River water within the constraints of the Water Power licence granted by the provincial government (hereinafter referred to as the hydrologic period 1912 to 1967).

The constraints are:

1) Southern Indian Lake can be regulated between elevations 844 and 847 feet,
2) Annual drawdown on Southern Indian Lake can not exceed two feet,
3) The flow at Notigi must not exceed 30,000 cfs on a weekly average, and
4) The flow in the Burntwood River at Thompson must not exceed 30,000 cfs plus the long term natural flow of 3500 cfs.

LOWER CHURCHILL RIVER

The lower Churchill River water regime also depends on the amount of water to be diverted from the Churchill River to the Nelson River system. The November 1927 to November 1966 hydrologic period was used in developing water level and flow information for this study area.

Manitoba Hydro provided modified historic outflows from Southern Indian Lake at Missi Falls. The SNBB provided mean monthly local inflow data at selected points along the lower Churchill River between Missi Falls and Hudson Bay.

For the condition with the Churchill River Diversion project in effect, Manitoba Hydro supplied mean monthly flows at Missi Falls. This data was derived by simulating the development sequence labelled AA-133H. This sequence assumes Lake Winnipeg Regulation in November 1974 and Churchill River Diversion in November 1975, the same as sequence GIJA.

Mean monthly water level and outflow information for Patridge Breast Lake, Northern Indian Lake, Fidler Lake and Billard Lake was prepared by the Water Resources Branch for both the modified historic case and the case with the diversion project in operation. This information was developed using water level-flow relationship curves prepared by the Water Resources Branch for the four lakes on the lower Churchill River and using the Missi Falls outflows and local inflows between Missi Falls and the respective lakes.

LOWER NELSON RIVER

The lower Nelson River, Split Lake to Hudson Bay, will be influenced by both the Lake Winnipeg regulation and the Churchill River Diversion projects.

The mean monthly modified historic outflows from Split Lake were provided by the SNBB. From these flows and using a water level-flow relationship provided by Manitoba Hydro, Split Lake mean monthly levels were computed by the Water Resources Branch. The hydrologic period of record used was from November 1927 to November 1966, the same period as used for Lake Winnipeg information. Manitoba hydro provided the mean monthly Split Lake outflow data from its system simulation sequence labelled AA-133H. This sequence assumes Lake Winnipeg Regulation in November 1974 and Churchill River Diversion in November 1975, the same as sequence GIJA. However, Manitoba Hydro indicated that sequence AA-133H was more representative of current development planning along the Rat-Burntwood diversion route and should be used for the lower Nelson River region.

INFORMATION PROVIDED

The information provided in this document includes:

a) Summaries of minimum, average and maximum mean monthly water levels and flows for each month and for the year.

b) Summaries of the minimum, average and maximum mean monthly fluctuations in water levels and flows from one month to the next.

c) Mean monthly water level and flow duration curves.

This information is provided for all sections listed below except where noted.

Section 1 - Lake Winnipeg Study Area

a) Lake Winnipeg Levels

b) Lake Winnipeg Outflows

Section 2 - Outlet Lakes Study Area

a) Nelson River (East Channel) Flows

b) Nelson RIver (West Channel) Flows

c) Playgreen Lake (South End) Levels

d) Playgreen Lake (North End) Levels

e) Kiskittogisu Lake Levels

f) Kiskitto Lake Level Duration Curve -
Supplied directly by Manitoba Hydro
(Ref. Drawing Manitoba Hdyro
No. 0510-A-9504).

g) Cross Lake Levels

Section 3 - Diversion Route Study Area

a) Notigi Control Structure Flows

b) Wuskwatim Power Site FLows

Section 4 - Southern Indian Lake Study Area

a) Southern Indian Lake Levels

b) Southern Indian Lake Outflows (Missi Falls)

c) Southern Indian Lake Inflows -
Modified Historic condition only

Section 5 - Lower Churchill River Study Area

a) Partridge Breast Lake Levels

b) Partride Breast Lake OUtflows

c) Northern Indian Lake Levels

d) Northern Indian Lake Outflows

e) Fidler Lake Levels

f) Fidler Lake Outflows

g) Billard Lake Levels

h) Billard Lake OUtflows

Section 6 - Lower Nelson River Study Area

a) Nelson River FLows at the Outlet of Split Lake

SECTION 1

LAKE WINNIPEG STUDY AREA

Lake Winnipeg Levels

LAKE WINNIPEG - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

Range In Feet	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	89	11	92	8	97	3	95	5	84	16	79	21	66	34	16	84	3	97	0	100	21	79	61	39
1 - 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 - 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	709.97	710.17	710.34	710.59	710.89	711.01	710.82	710.46	710.03	709.74	709.67	709.78	709.67
AVERAGE	713.06	713.15	713.25	713.40	713.61	713.81	713.90	713.74	713.39	713.07	712.92	712.95	713.35
MAXIMUM	715.55	715.55	715.64	715.82	716.39	717.00	717.16	716.77	716.05	715.66	715.57	715.53	717.16

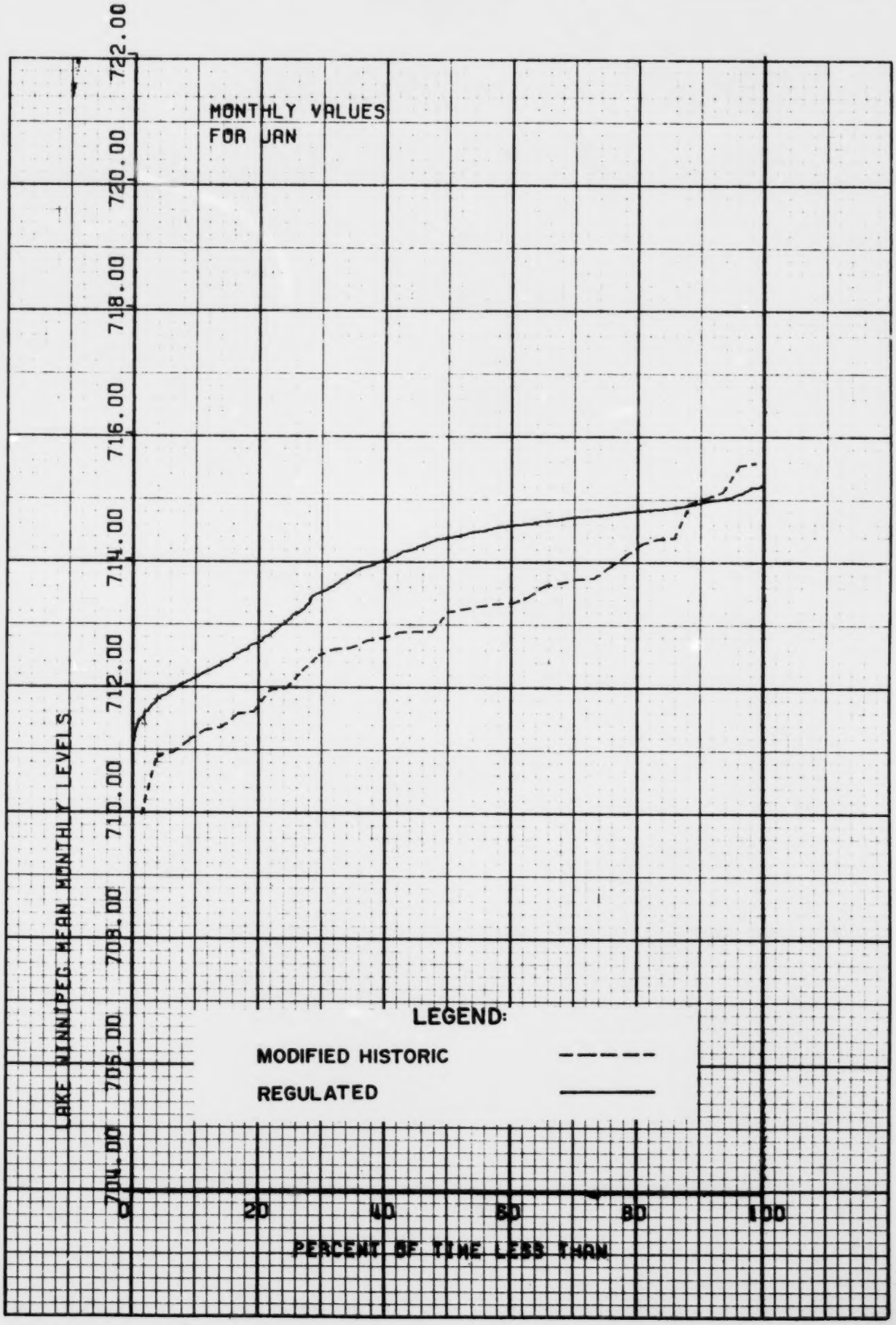
LAKE WINNIPEG - REGULATED CONDITIONS

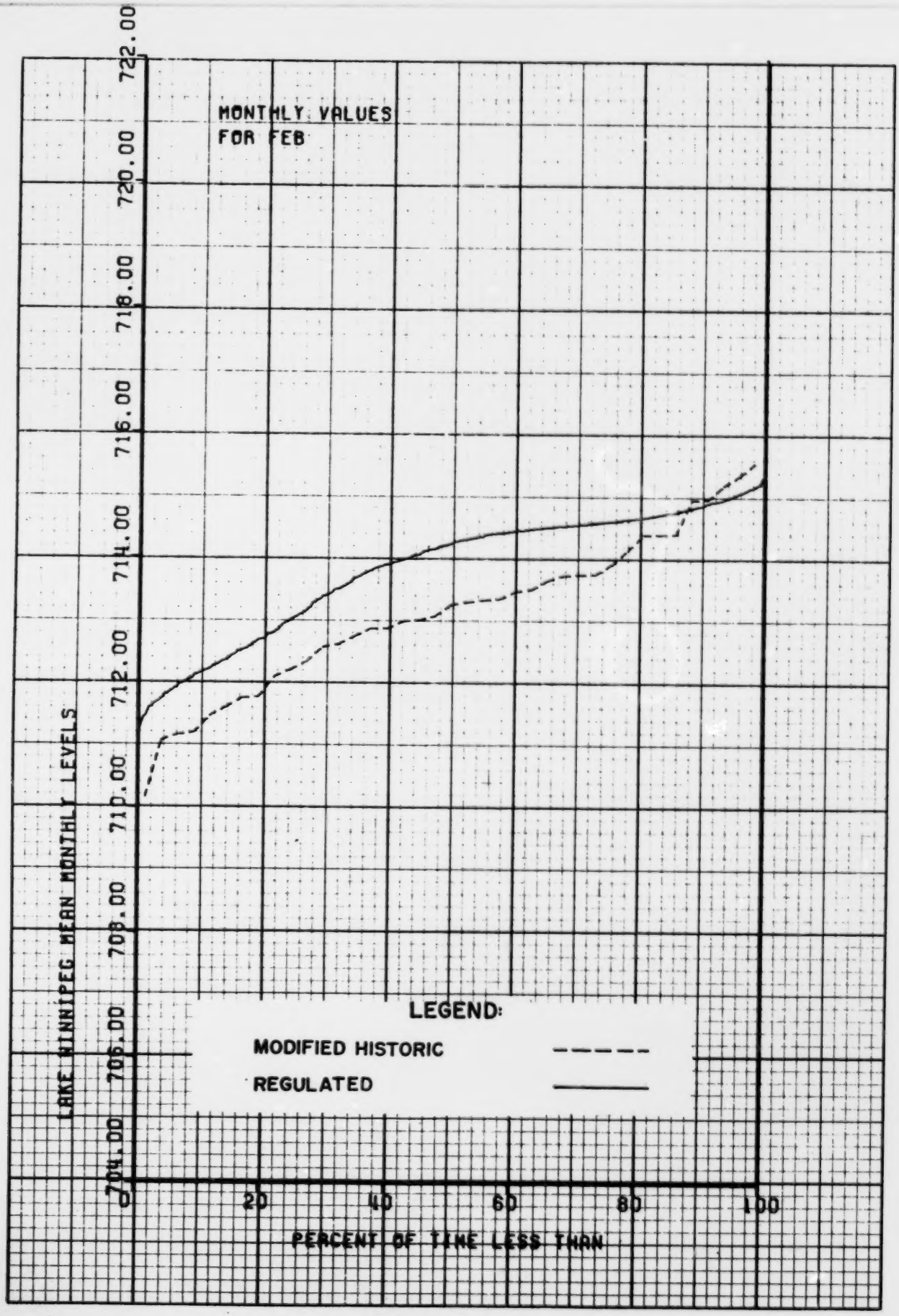
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

Range In Feet	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	30	70	27	73	20	80	44	56	79	21	88	12	85	15	70	30	47	53	38	62	30	70	12	88
1 - 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 - 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	711.11	711.10	711.19	711.39	711.68	711.93	711.98	711.86	711.63	711.43	711.22	711.11	711.10
AVERAGE	713.90	713.82	713.90	713.66	713.83	714.09	714.26	714.32	714.26	714.16	714.09	713.95	714.00
MAXIMUM	715.23	715.31	715.24	715.35	716.07	716.50	716.40	716.12	715.58	715.11	715.60	715.28	716.50


MONTHLY VALUES
FOR JAN
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR FEB
LAKE WINNIPEG MEAN MONTHLY LEVELS
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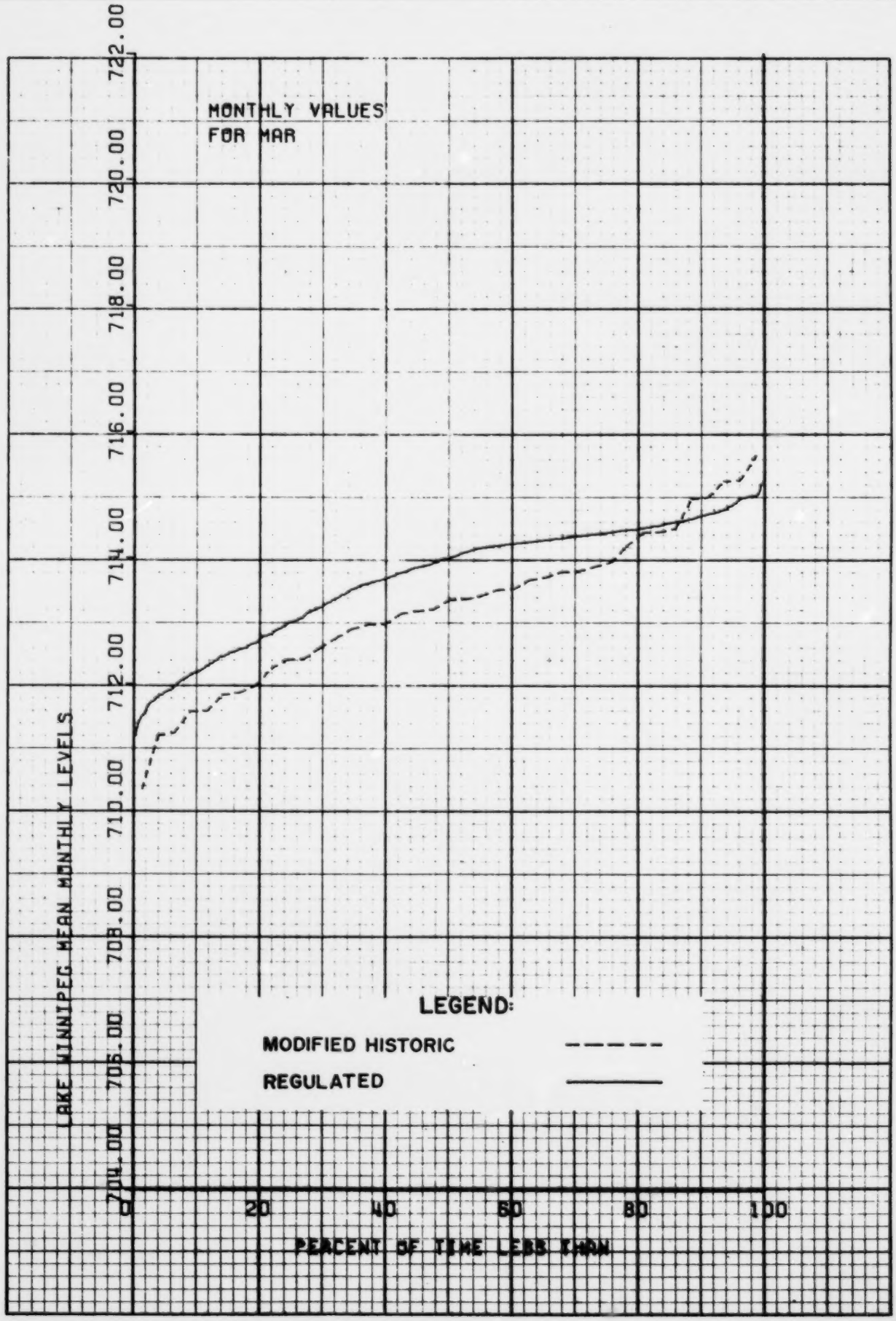
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR MAR
LAKE WINNIPEG MEAN MONTHLY LEVELS
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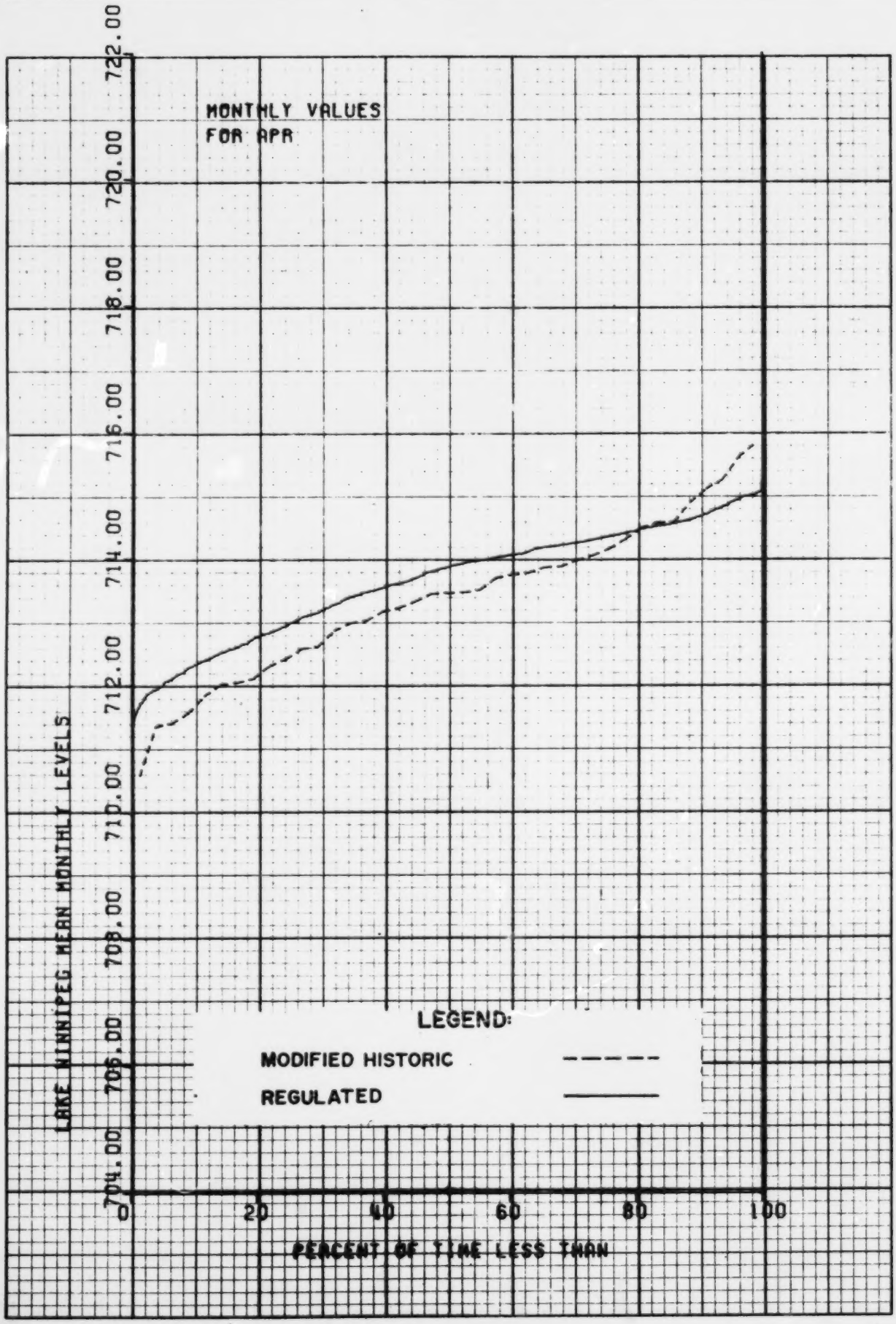
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED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FOR APR
LAKE WINNIPEG MEAN MONTHLY LEVELS
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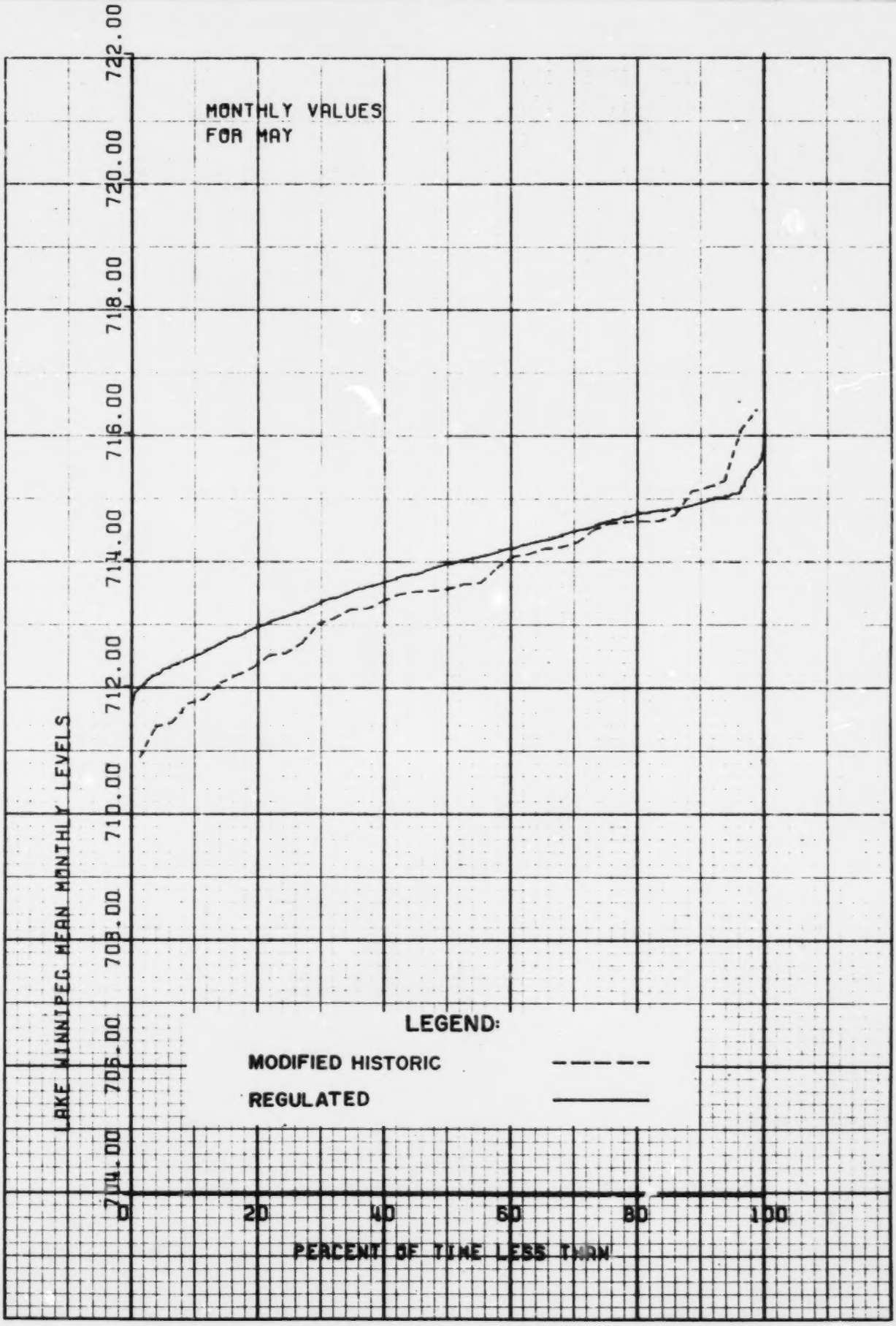
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED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FOR MAY
LAKE WINNIPEG MEAN MONTHLY LEVELS
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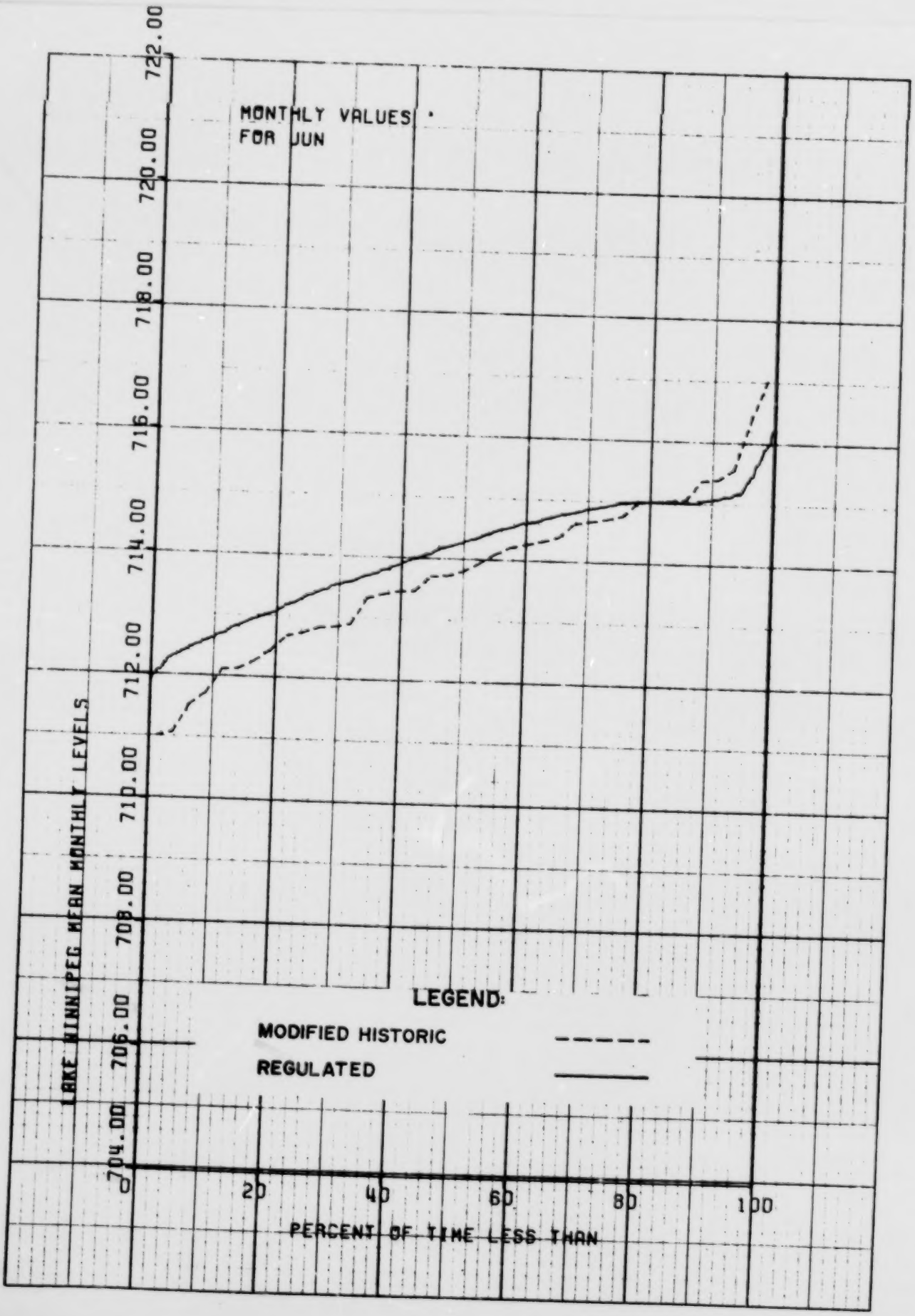
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR JUN
LAKE WINNIPEG MEAN MONTHLY LEVELS
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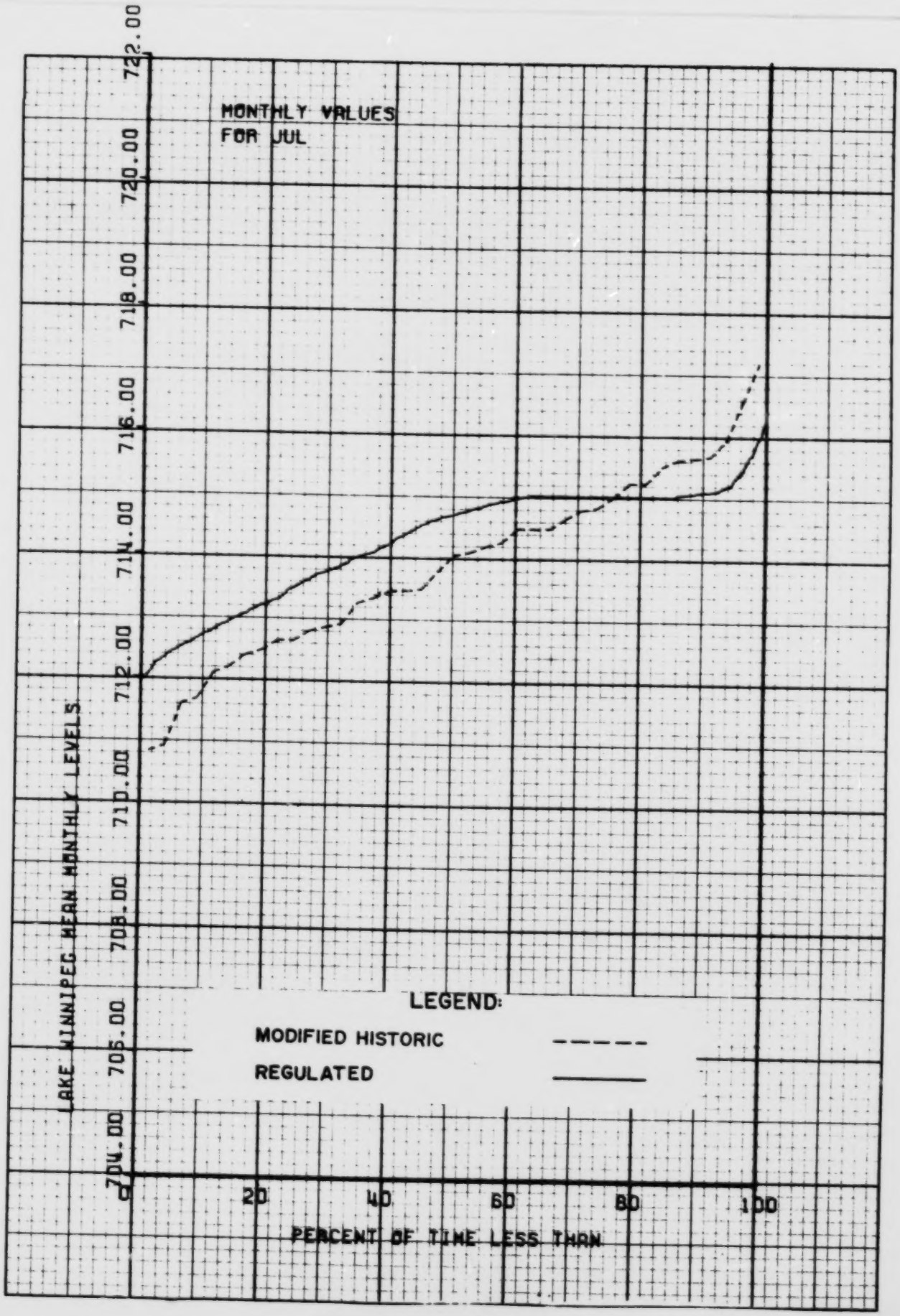
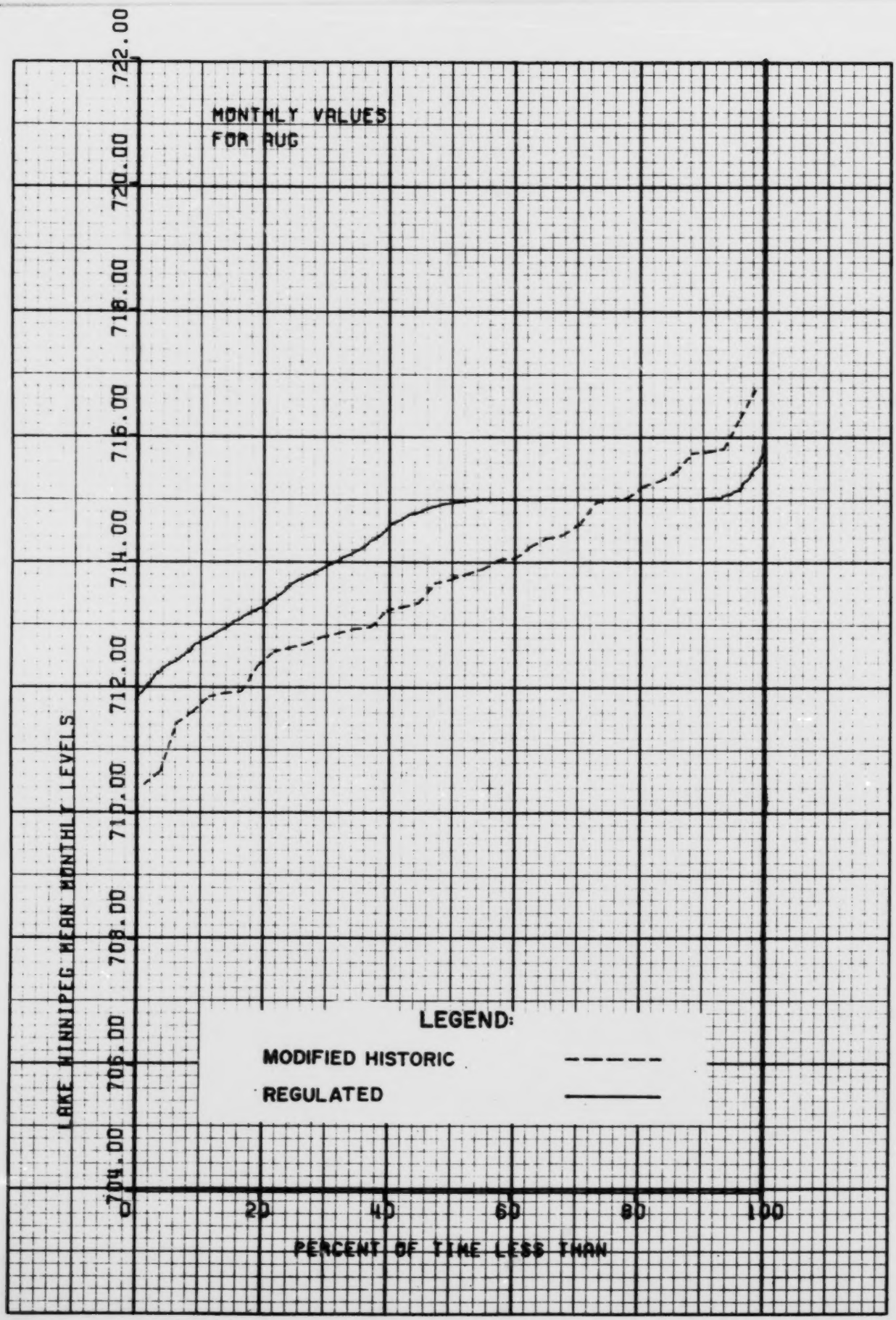
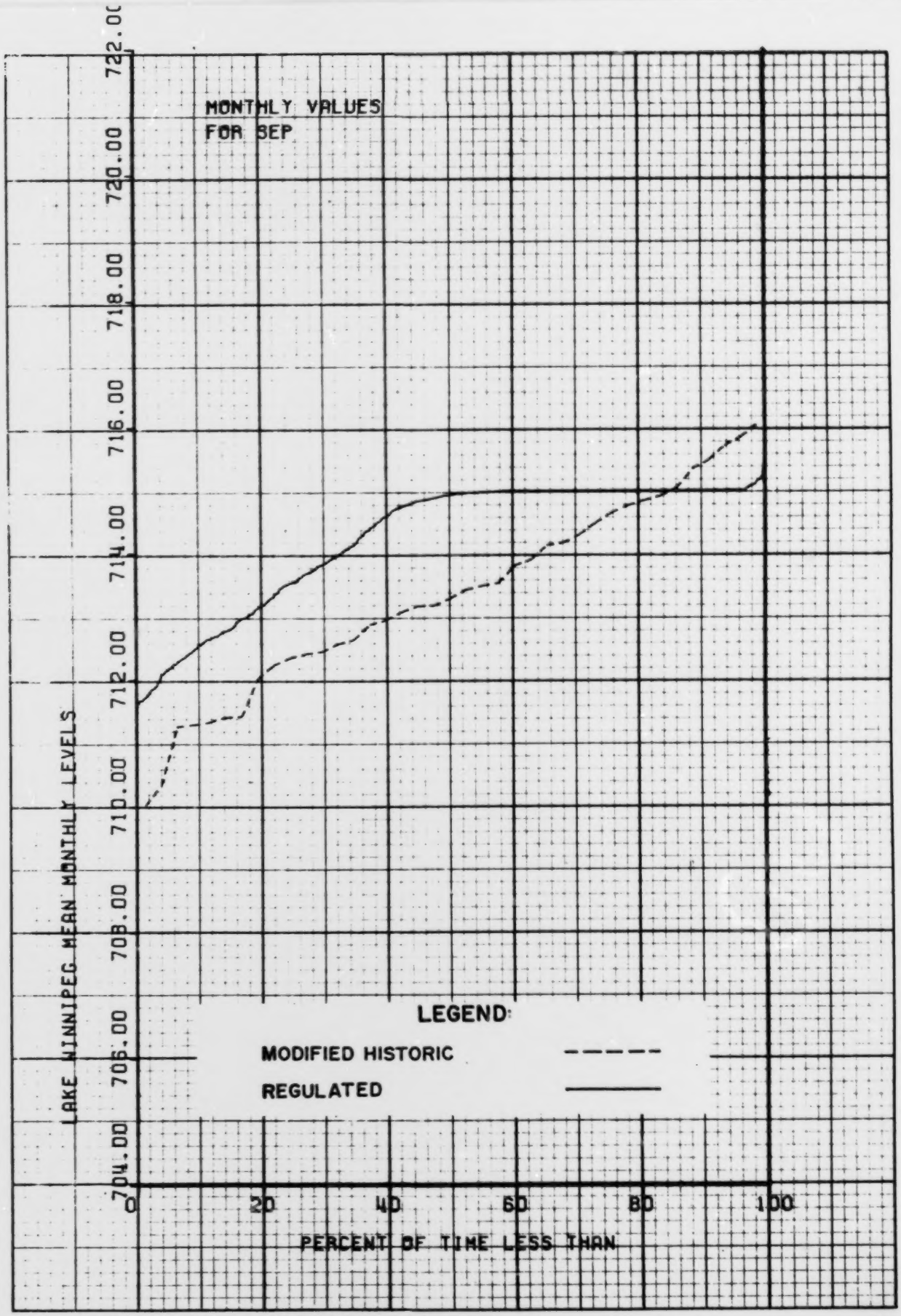
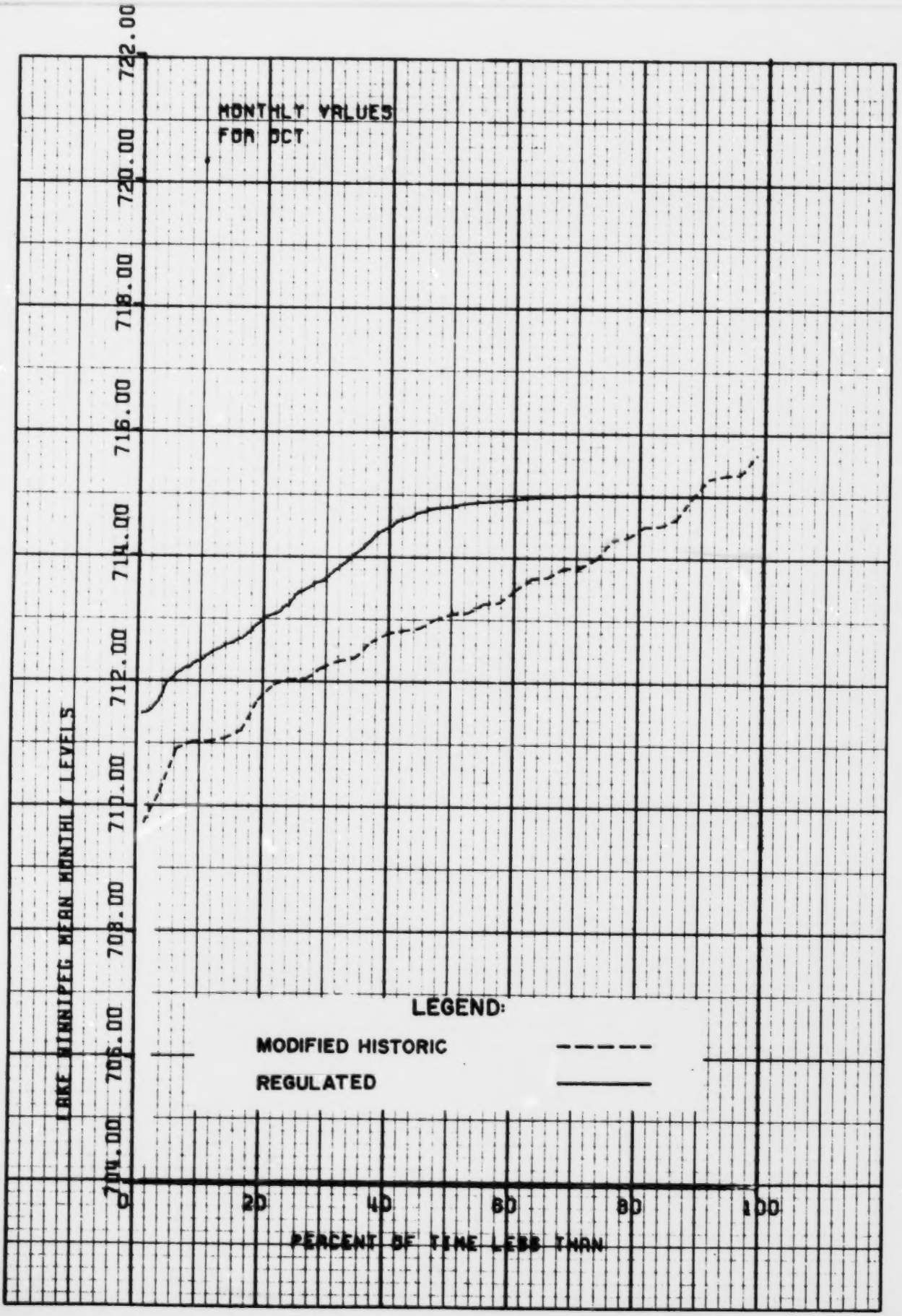
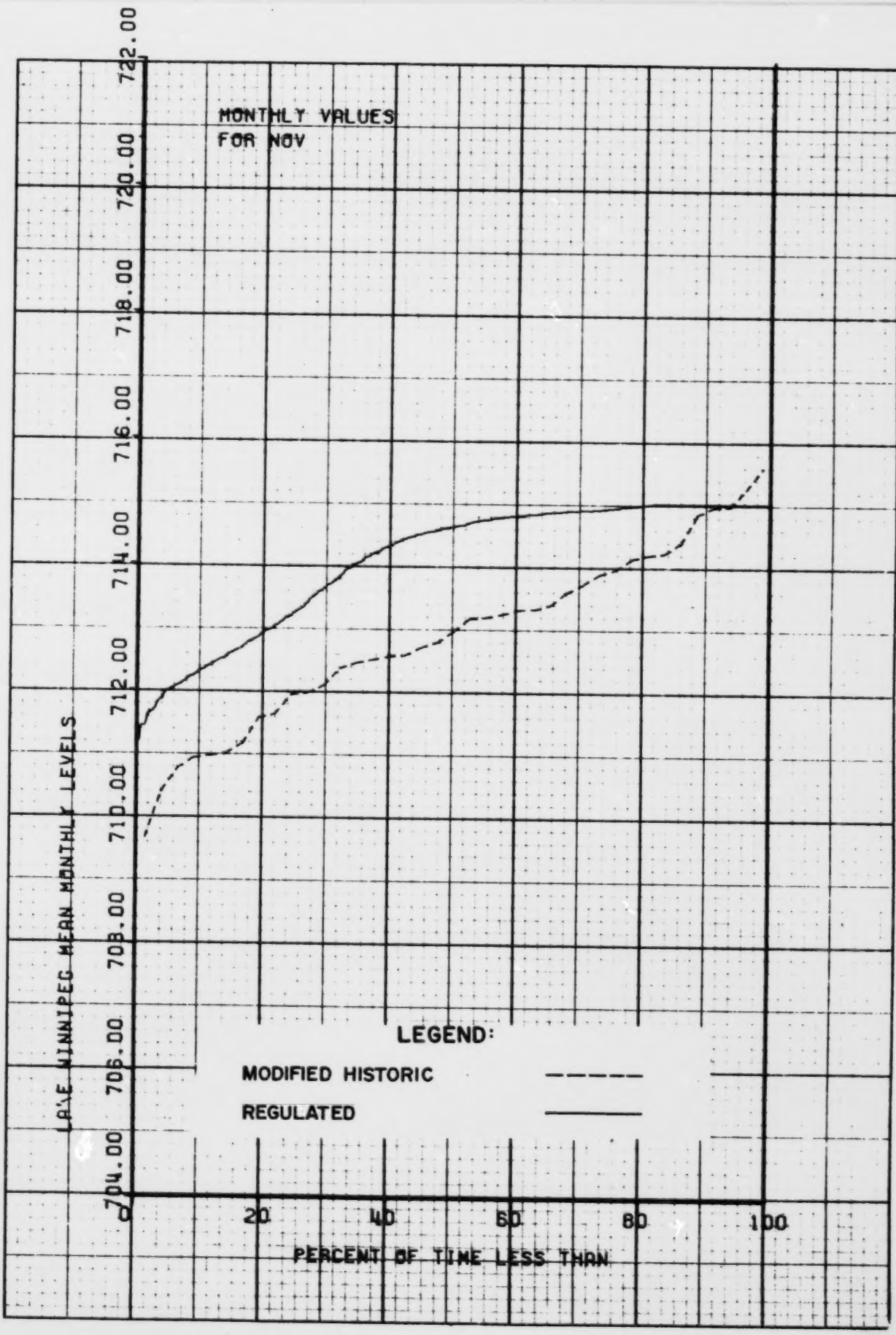
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED

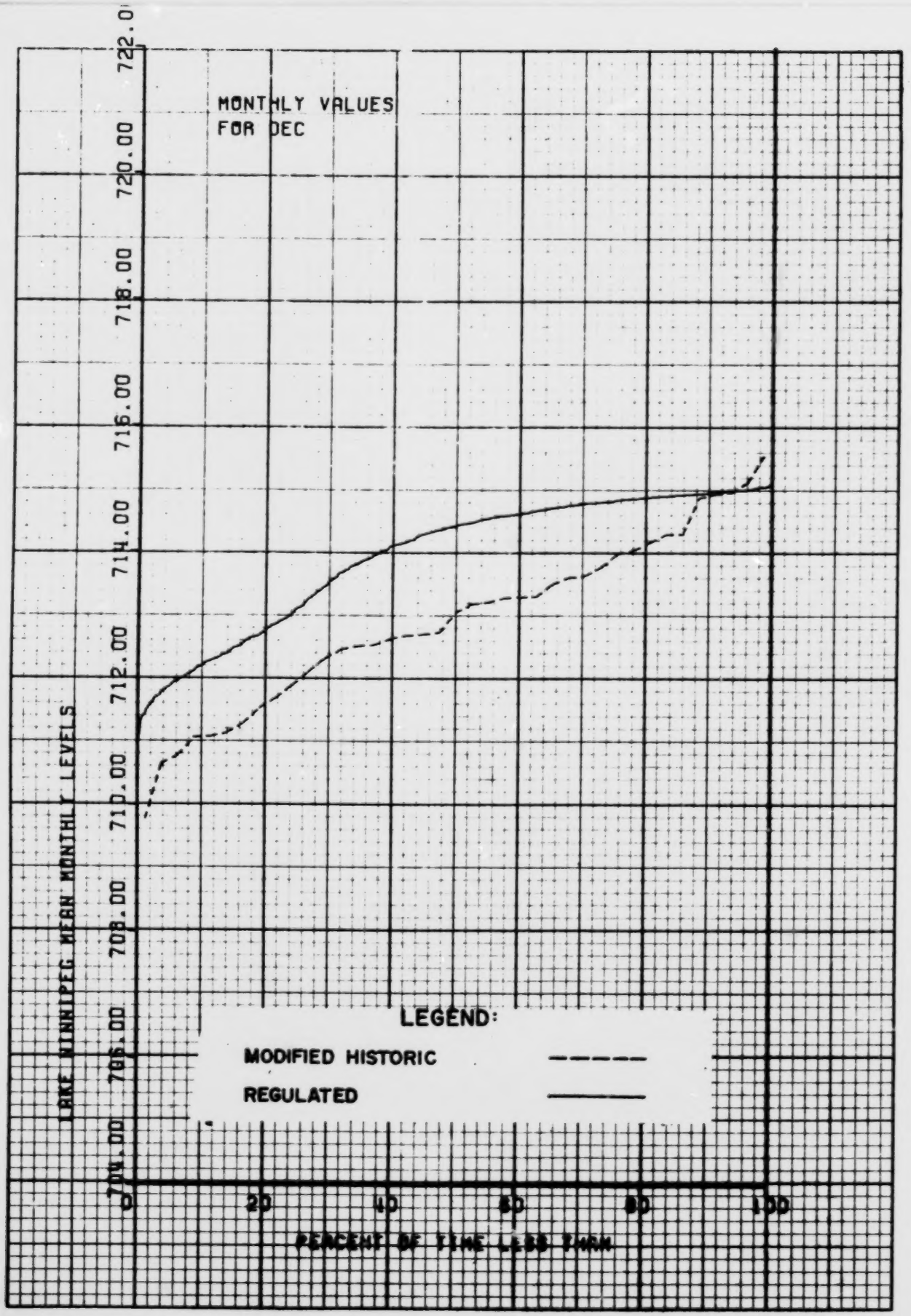

MONTHLY VALUES
FOR JUL
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR AUG
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR SEP
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR OCT
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
LEGEND:
MODIFIED HISTORIC
REGULATED
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.00
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR DEC
LAKE WINNIPEG MEAN MONTHLY LEVELS
722.0
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
LEGEND:
MODIFIED HISTORIC
REGULATED
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

LAKE WINNIPEG
OUTFLOWS

(Revised Oct./74)

LAKE WINNIPEG - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	3	74	45	55	95	5	0	0	0	0	37	3	24	61	11	71	3	63	0	74	3	13	0	0
5 - 10	0	24	0	0	0	0	26	0	0	0	39	0	11	5	0	16	0	32	0	24	0	71	0	0
10 - 20	0	0	0	0	0	0	74	0	79	0	21	0	0	0	0	3	0	3	0	3	0	13	0	100
20 - 30	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

													ANNUAL
MINIMUM	16,311	17,007	18,570	28,038	47,994	52,866	51,655	47,551	42,983	40,020	34,277	20,218	16,311
AVERAGE	50,813	50,535	51,677	62,849	80,819	87,636	87,600	84,487	80,208	76,365	69,069	55,151	69,767
MAXIMUM	83,590	81,440	82,600	97,530	123,850	142,890	144,050	132,650	118,890	110,530	101,120	87,730	144,050

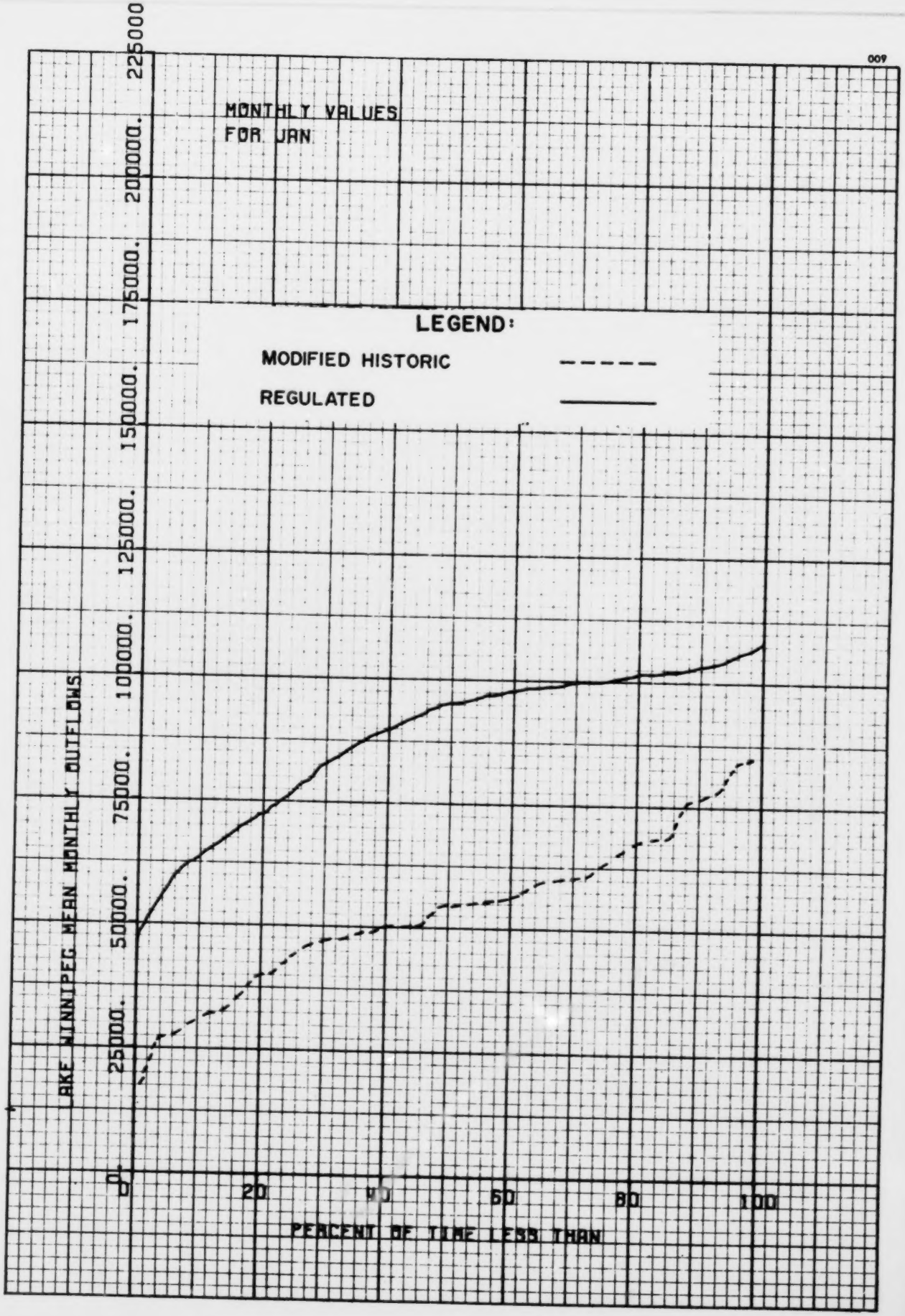
LAKE WINNIPEG - REGULATED CONDITIONS

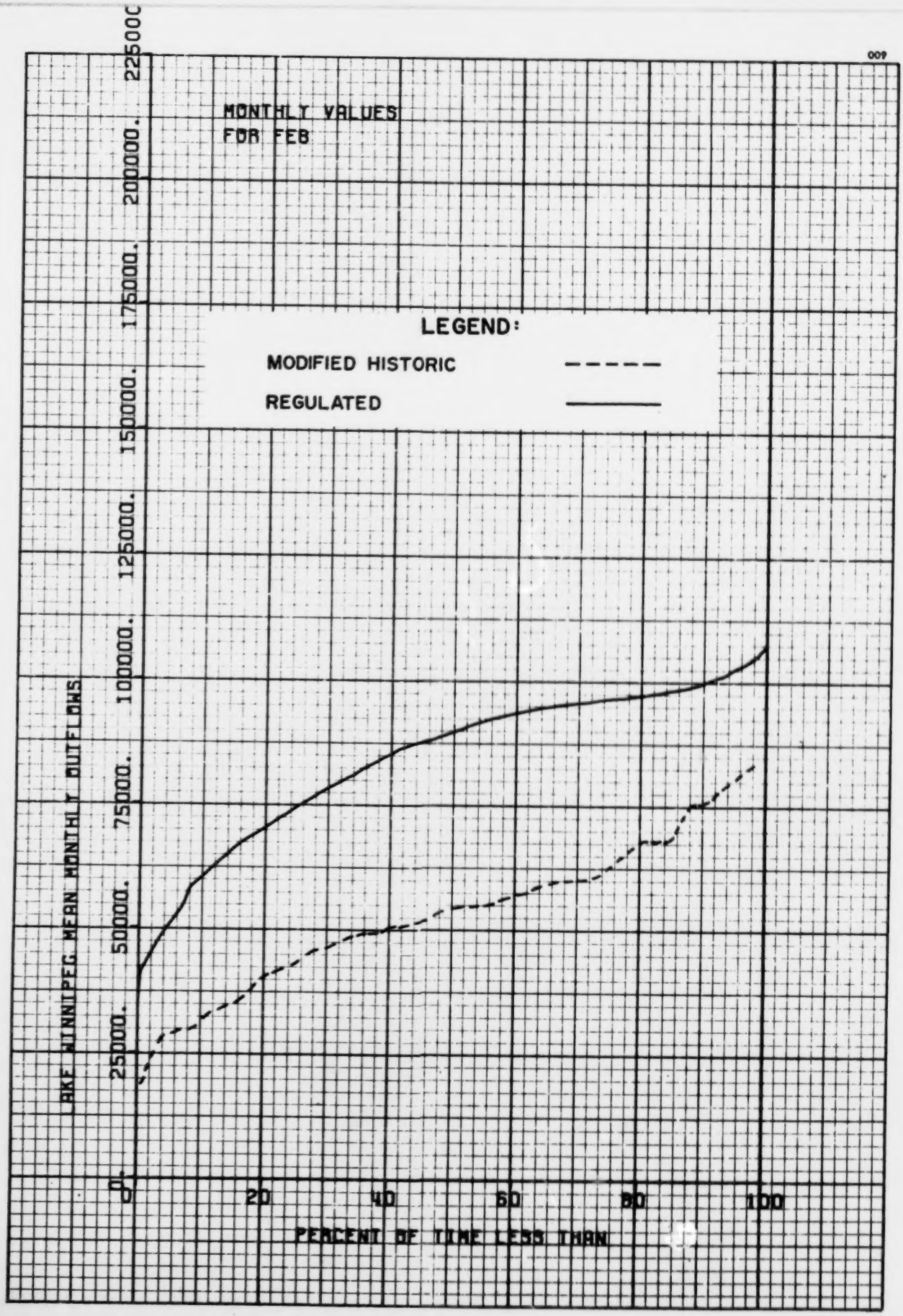
AVERAGE FLOW FLUCTUATIONS IN PERCENT

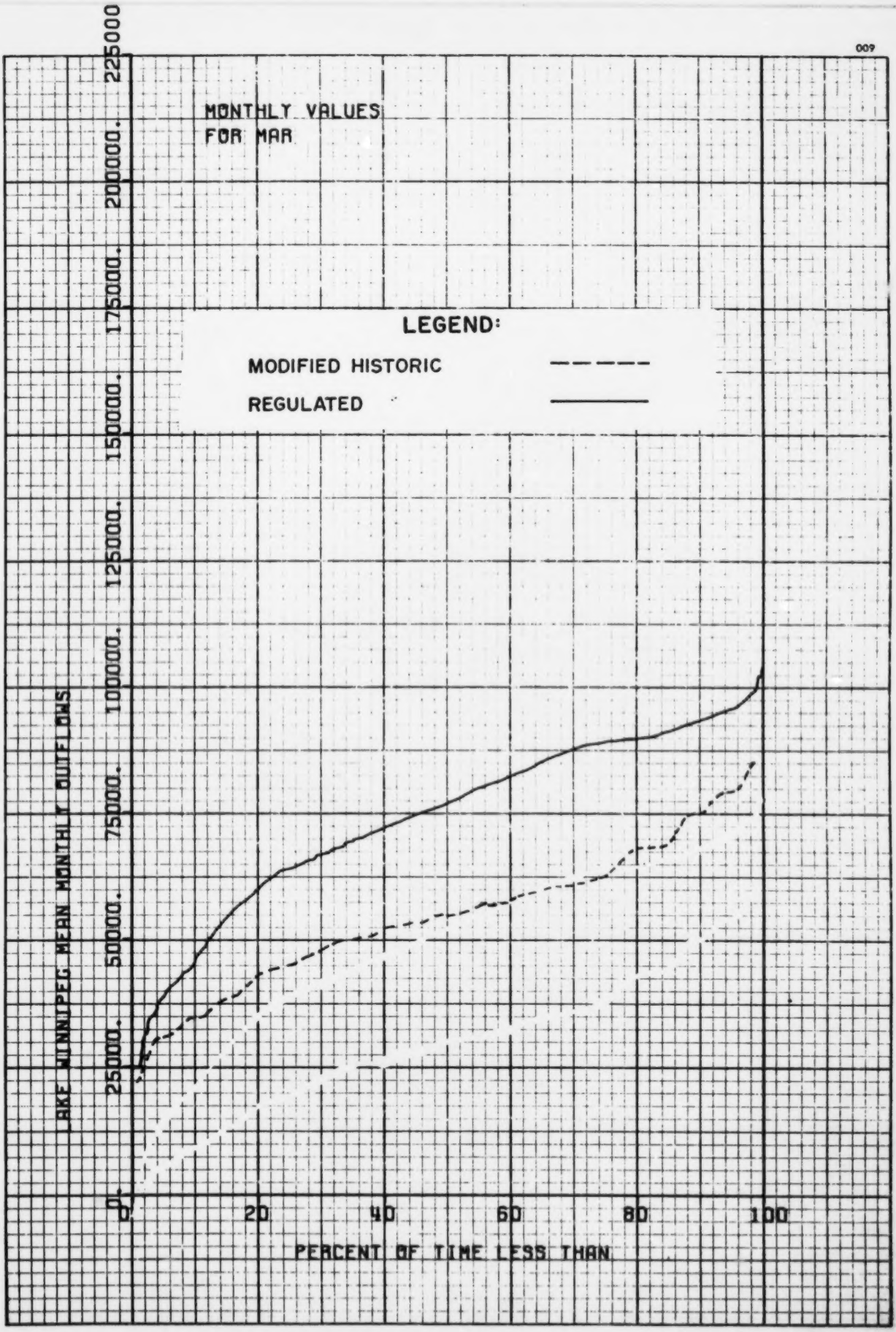
RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	4	39	4	77	1	25	13	21	5	7	6	7	21	18	18	9	10	10	15	8	11	4	6	5
5 - 10	6	45	0	13	1	41	2	12	4	13	4	14	4	11	16	6	20	5	17	7	10	4	8	6
10 - 20	5	0	0	5	0	17	3	24	6	23	10	18	4	8	6	6	23	5	19	13	25	4	11	6
20 - 30	1	0	0	1	0	10	2	17	10	7	11	4	3	8	1	13	3	10	4	9	8	4	11	18
30 - 40	0	0	0	0	0	5	0	6	9	3	6	2	3	2	2	3	2	5	2	1	8	2	17	1
40 -	0	0	0	0	0	0	0	0	12	1	12	6	10	8	3	17	2	5	3	2	20	0	11	0

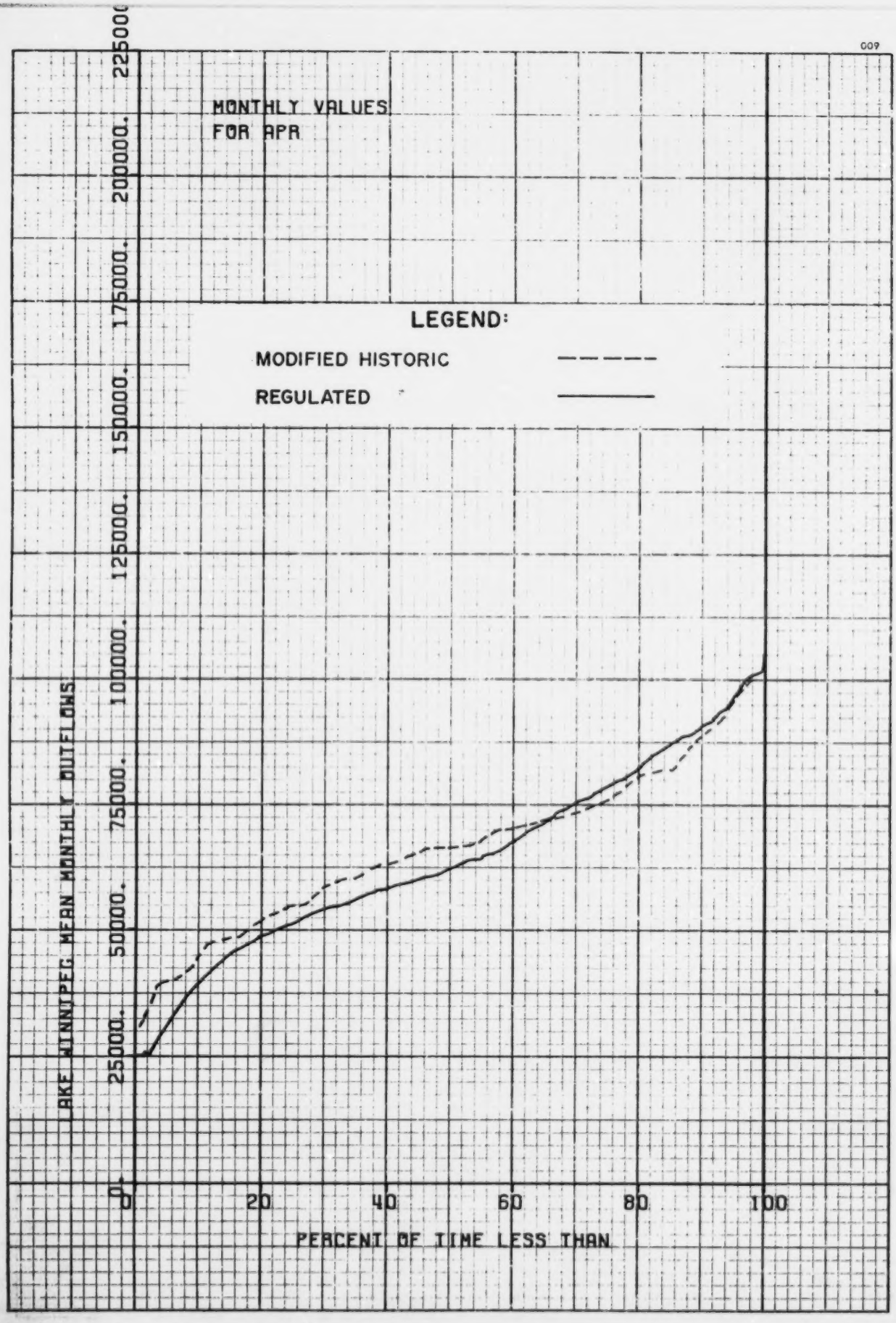
MEAN MONTHLY FLOWS IN CFS.

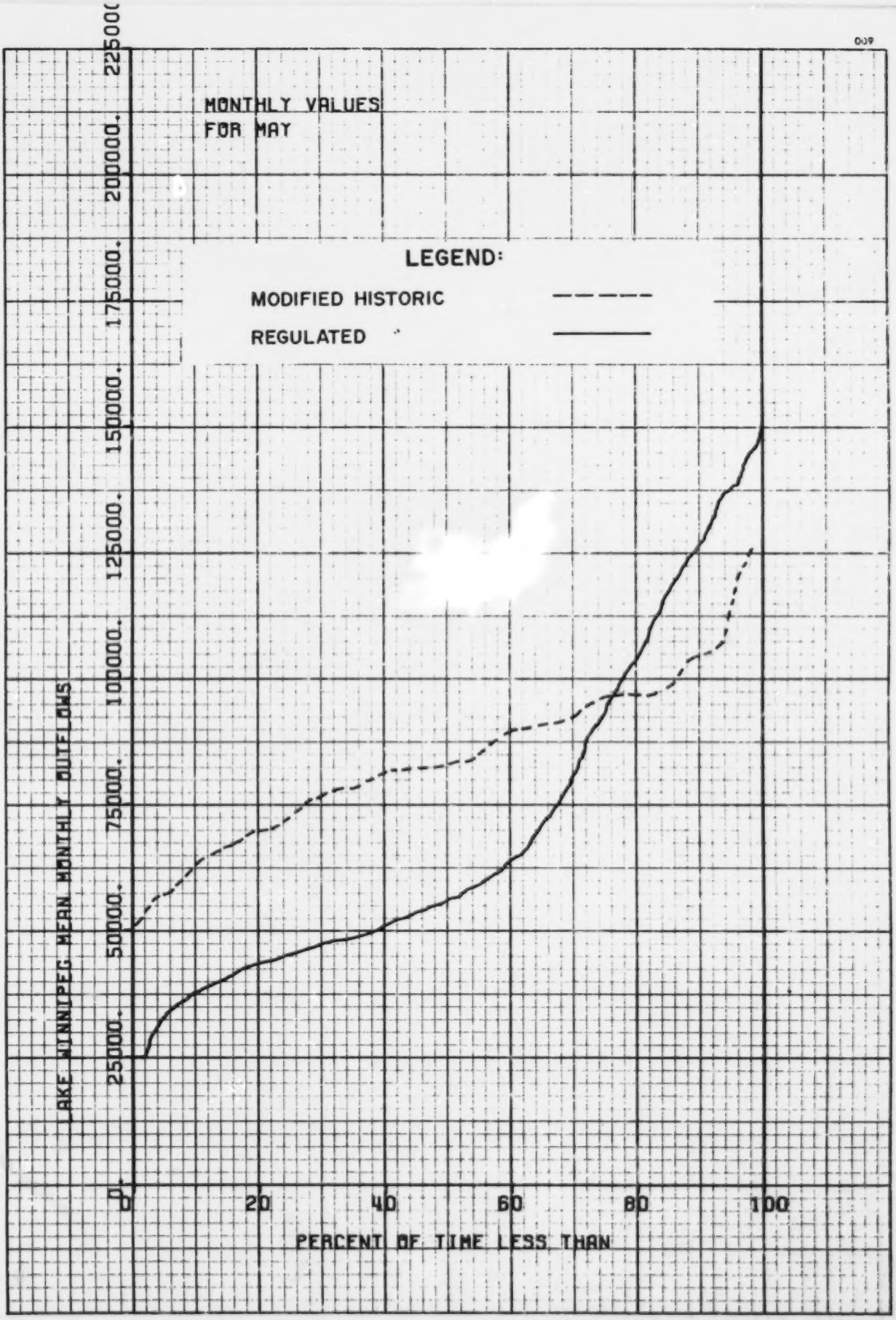
													ANNUAL
MINIMUM	43,110	35,590	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	31,509	25,000
AVERAGE	91,021	88,353	65,280	54,339	67,354	81,348	78,552	55,353	51,998	50,094	72,984	80,527	69,767
MAXIMUM	107,050	106,060	102,210	104,520	154,390	183,270	181,380	175,790	165,300	150,940	146,330	113,050	183,270

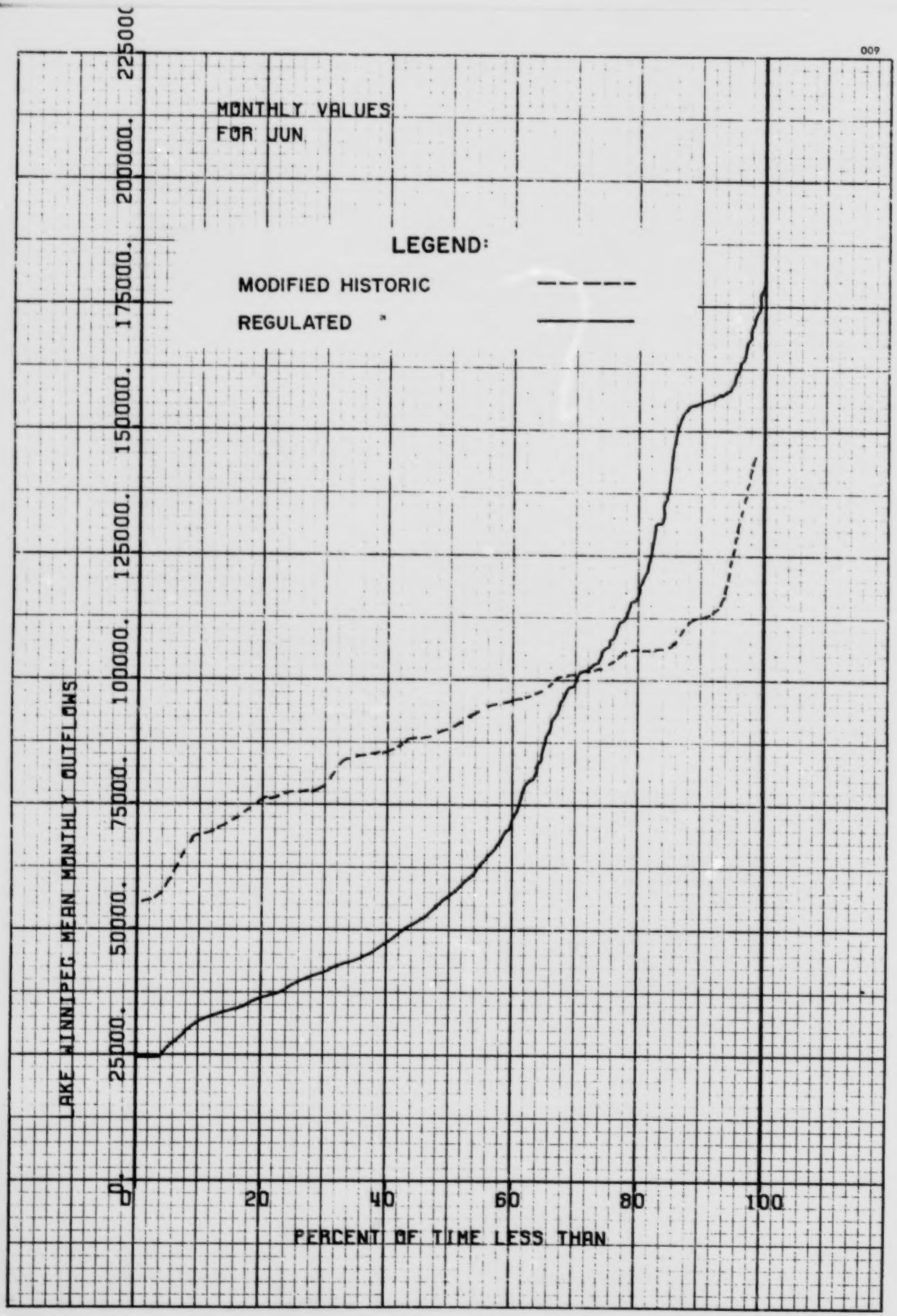

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
225000
200000.
175000.
150000.
125000.
100000.
75000.
50000.
25000.
0.
20
40
60
80
100
PERCENT OF TIME LESS THAN

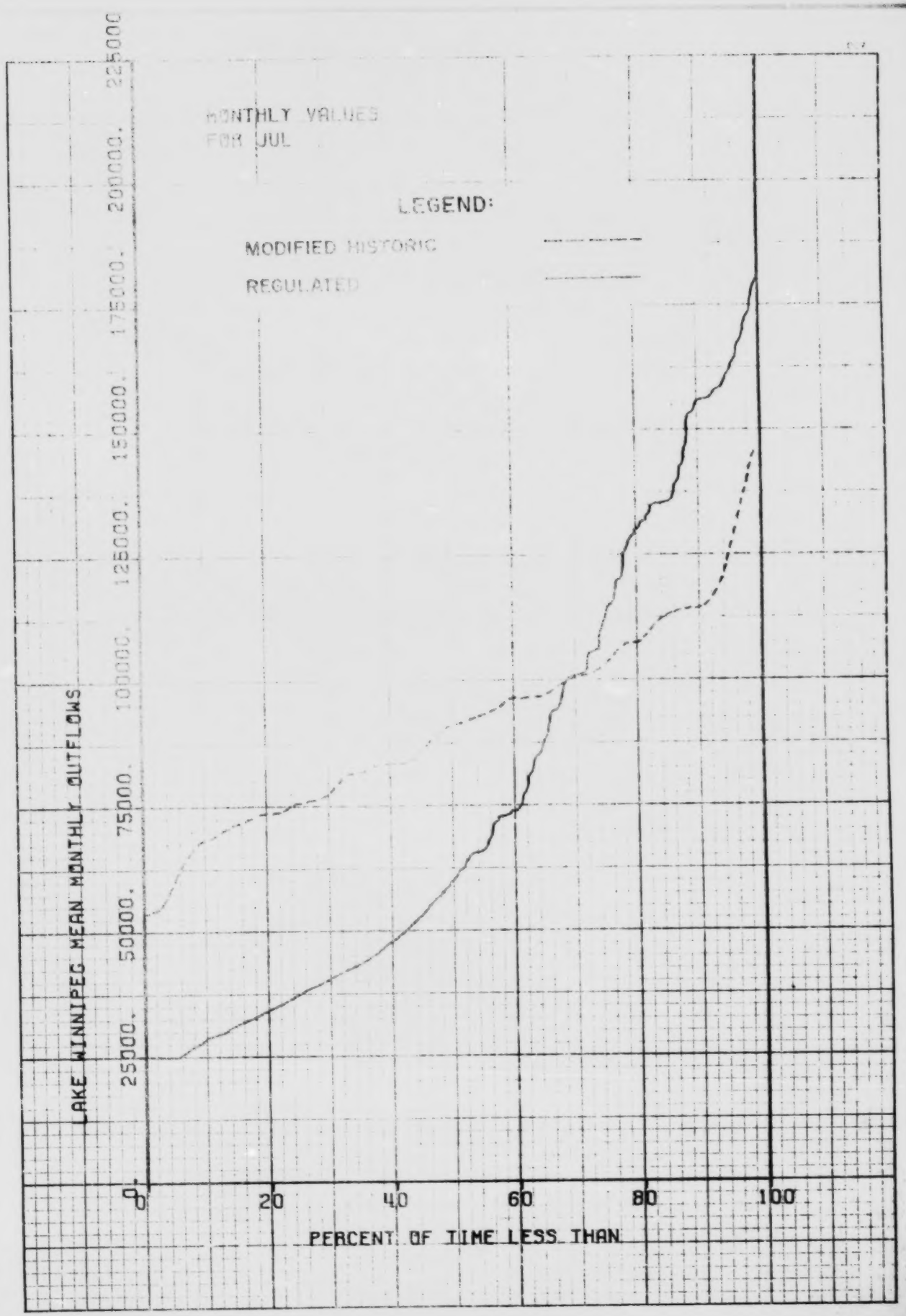

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

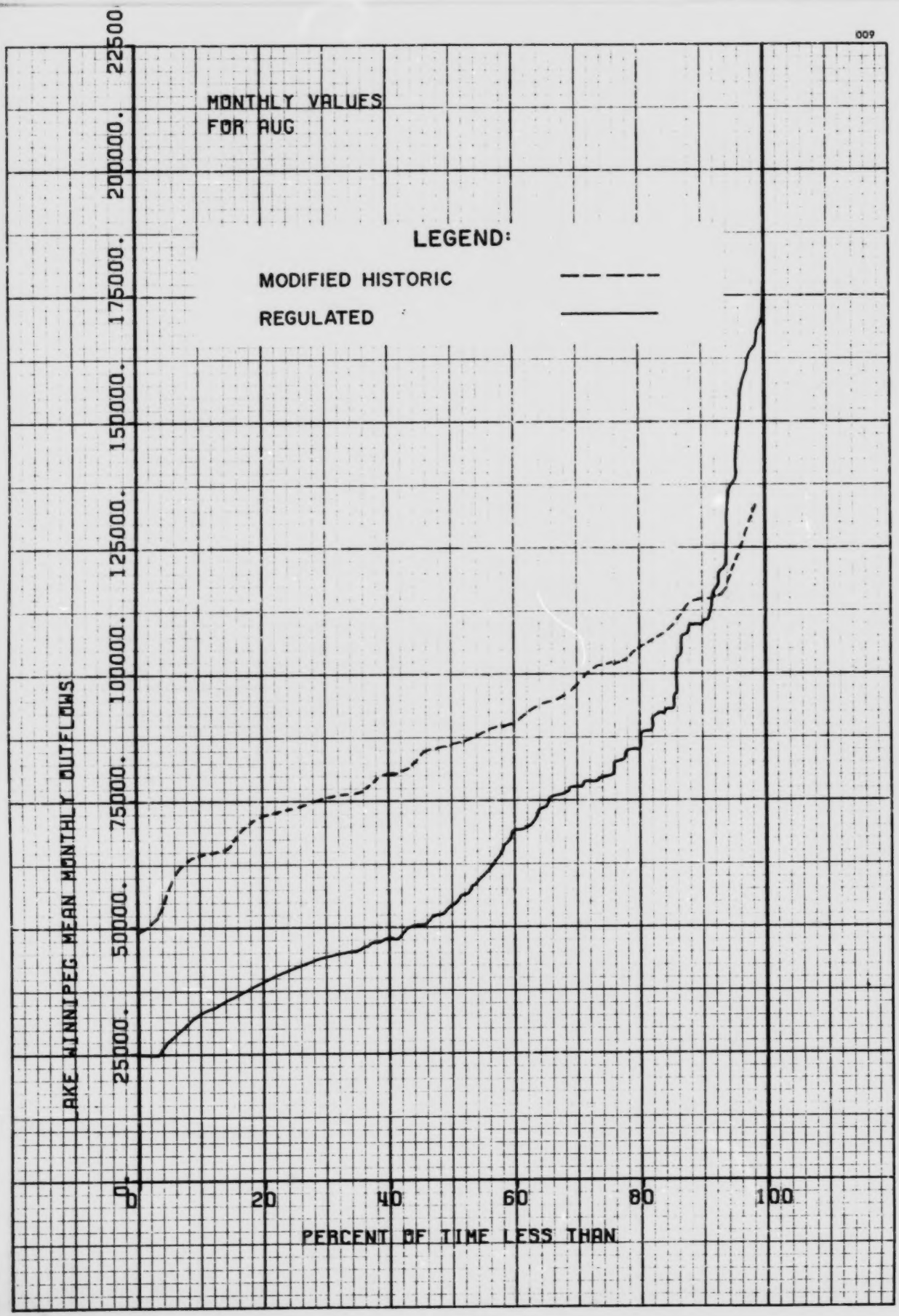

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

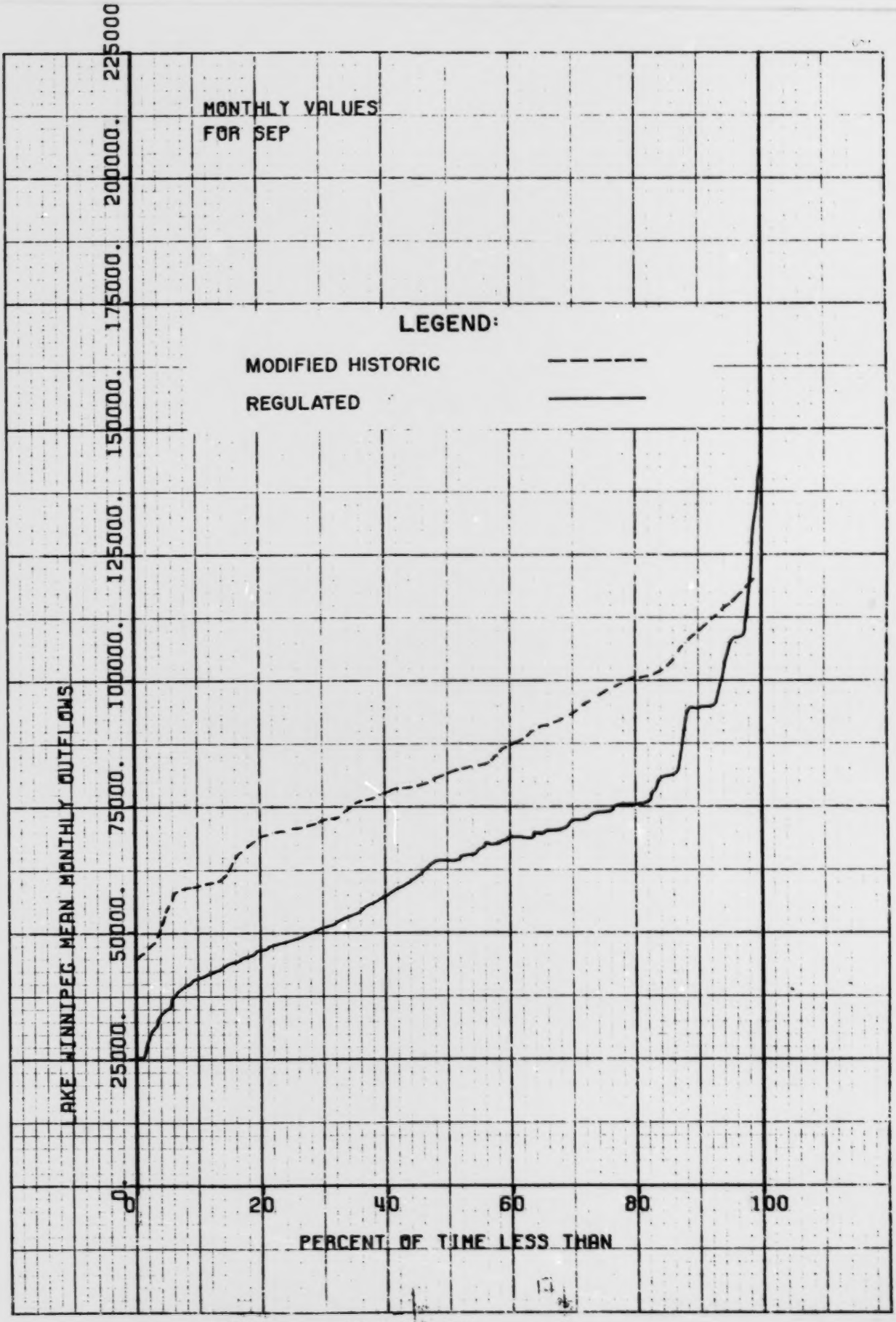

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

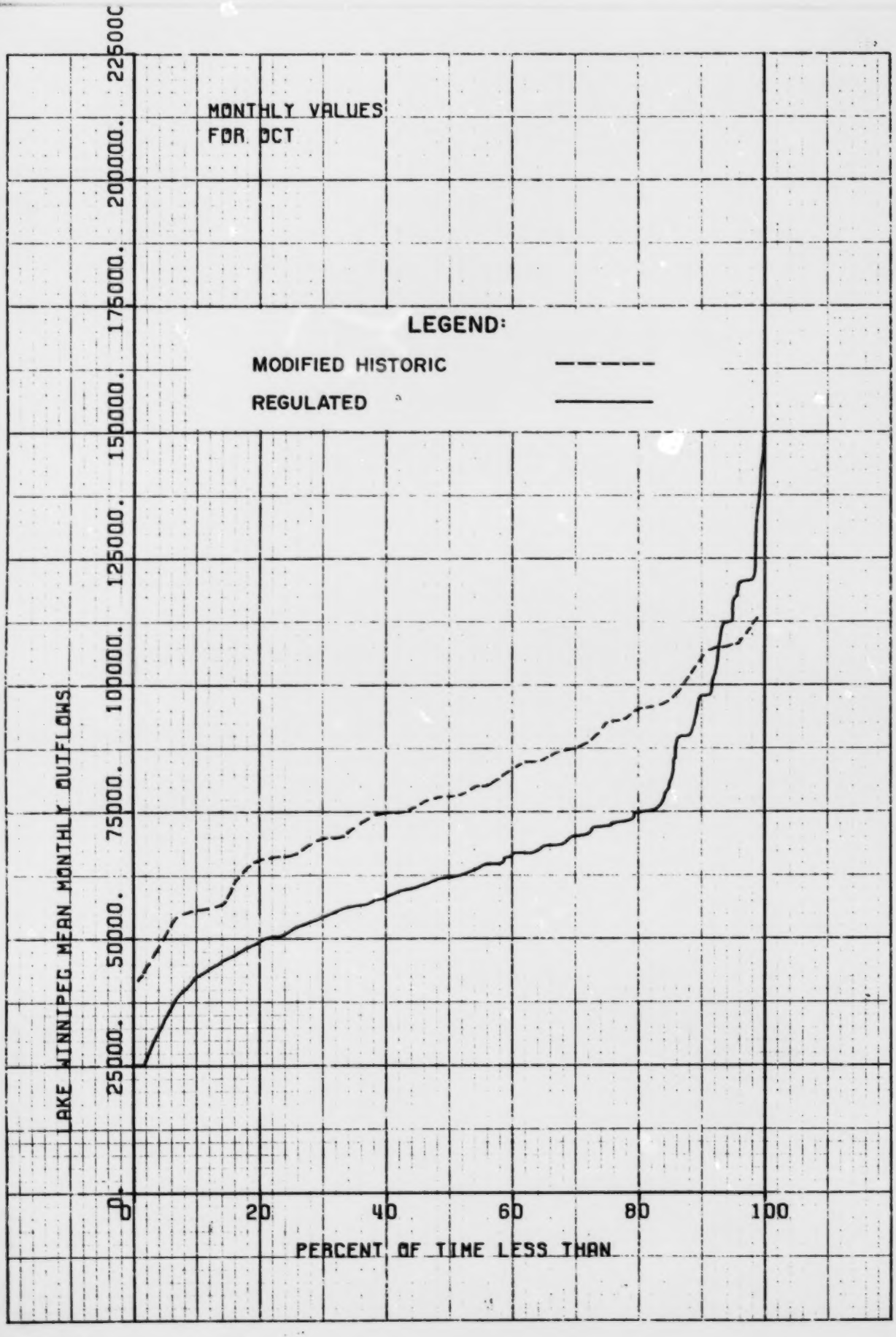

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

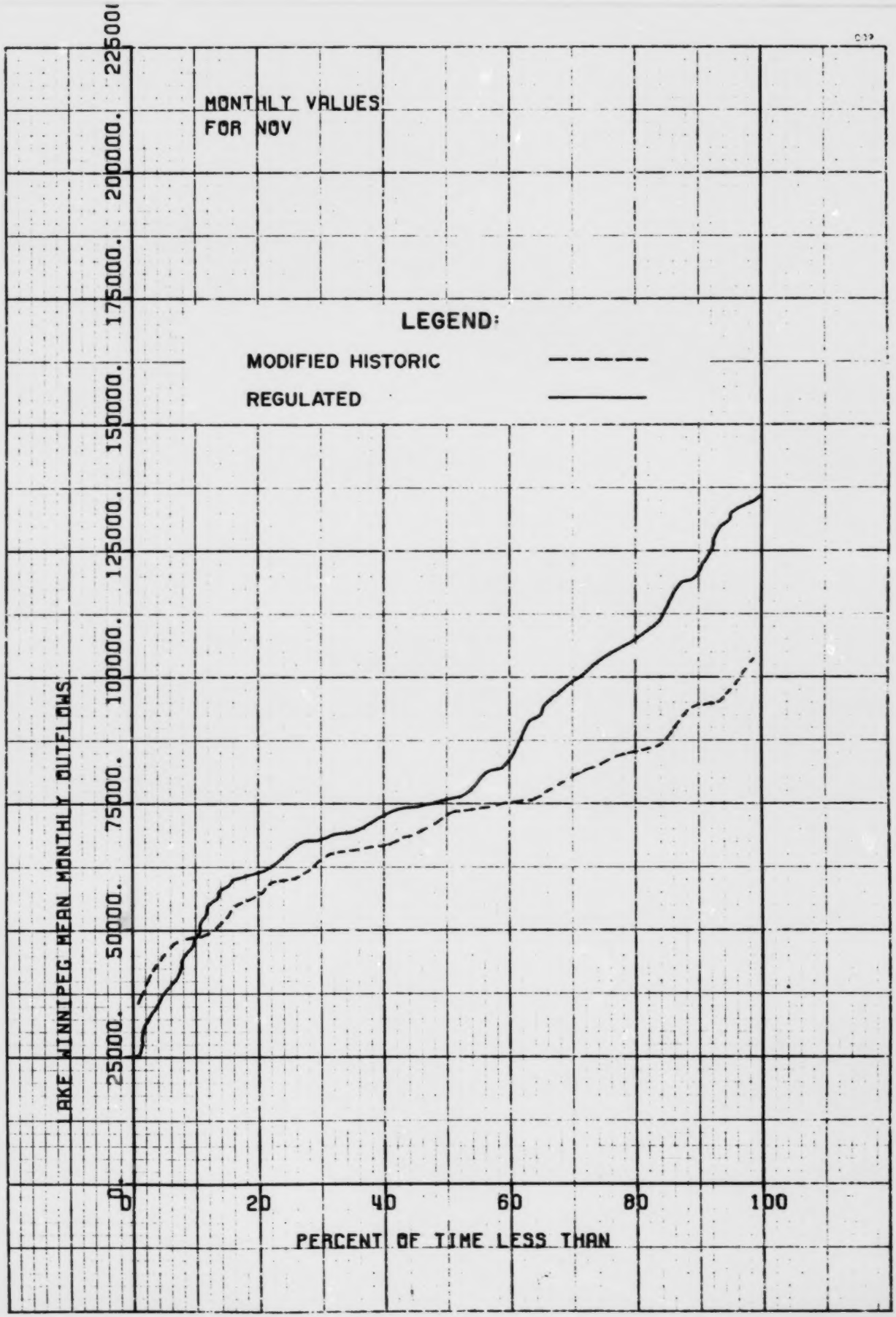

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

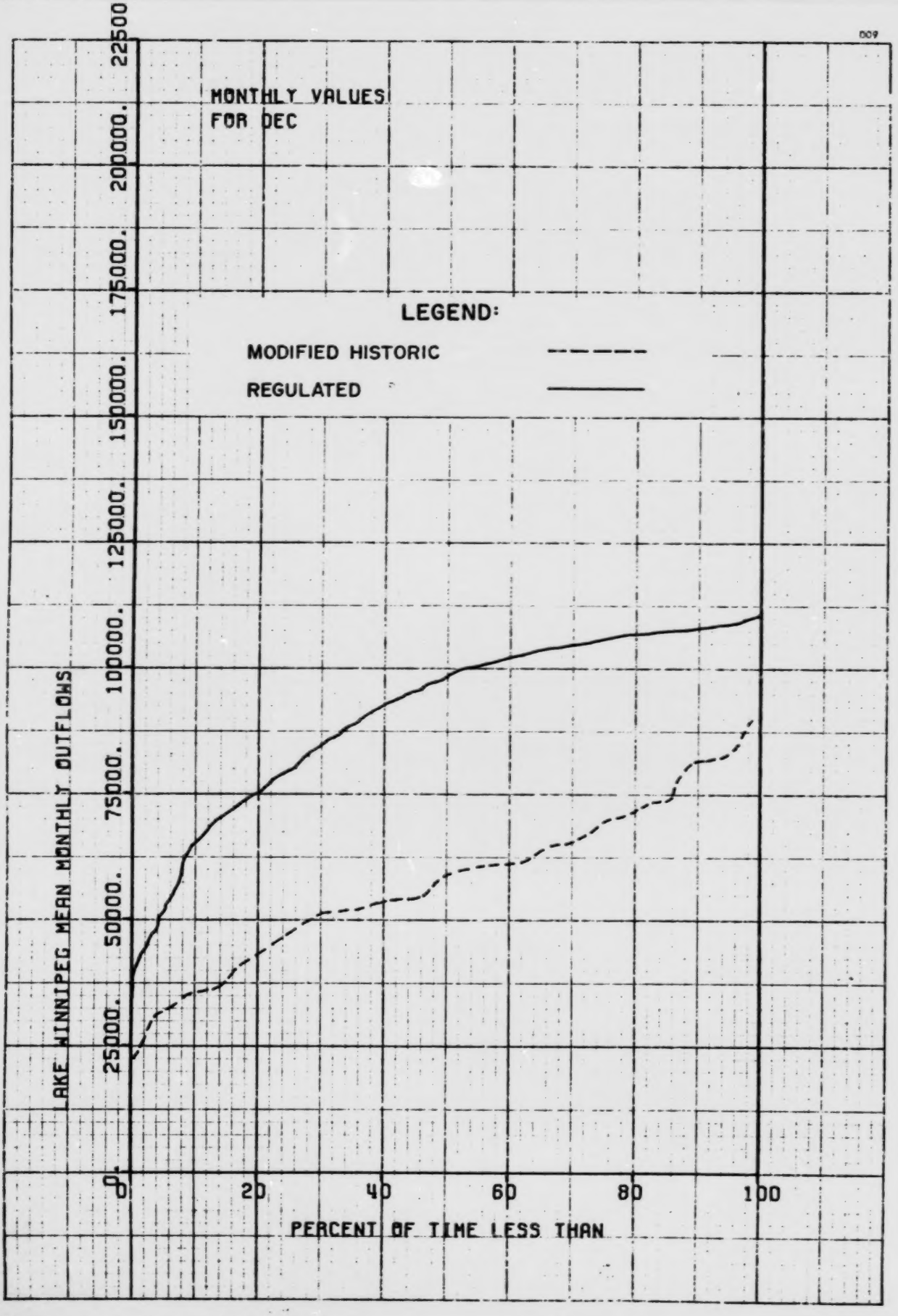

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
LAKE WINNIPEG MEAN MONTHLY OUTFLOWS
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SECTION 2

OUTLET LAKES STUDY AREA

Nelson River (East Channel)
Flows

(Revised Oct./74)

EAST CHANNEL - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	0	47	50	47	97	3	11	0	3	0	16	3	26	50	11	37	3	32	0	45	3	5	0	11
1 - 2	3	39	0	3	0	0	16	0	18	0	32	0	3	5	0	45	0	47	0	42	0	29	0	58
2 - 4	0	11	0	0	0	0	34	0	63	0	39	0	11	5	0	5	0	16	0	13	0	63	0	32
4 - 6	0	0	0	0	0	0	39	0	13	0	8	0	0	0	0	3	0	3	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

													ANNUAL
MINIMUM	175	260	345	810	2,430	3,110	2,875	2,290	1,805	1,605	1,120	445	175
AVERAGE	4,900	4,795	5,020	8,215	11,080	13,120	13,090	12,135	10,840	9,710	7,635	5,975	8,876
MAXIMUM	14,885	14,300	14,710	18,885	24,100	30,755	31,130	26,990	22,105	19,450	16,855	16,100	31,130

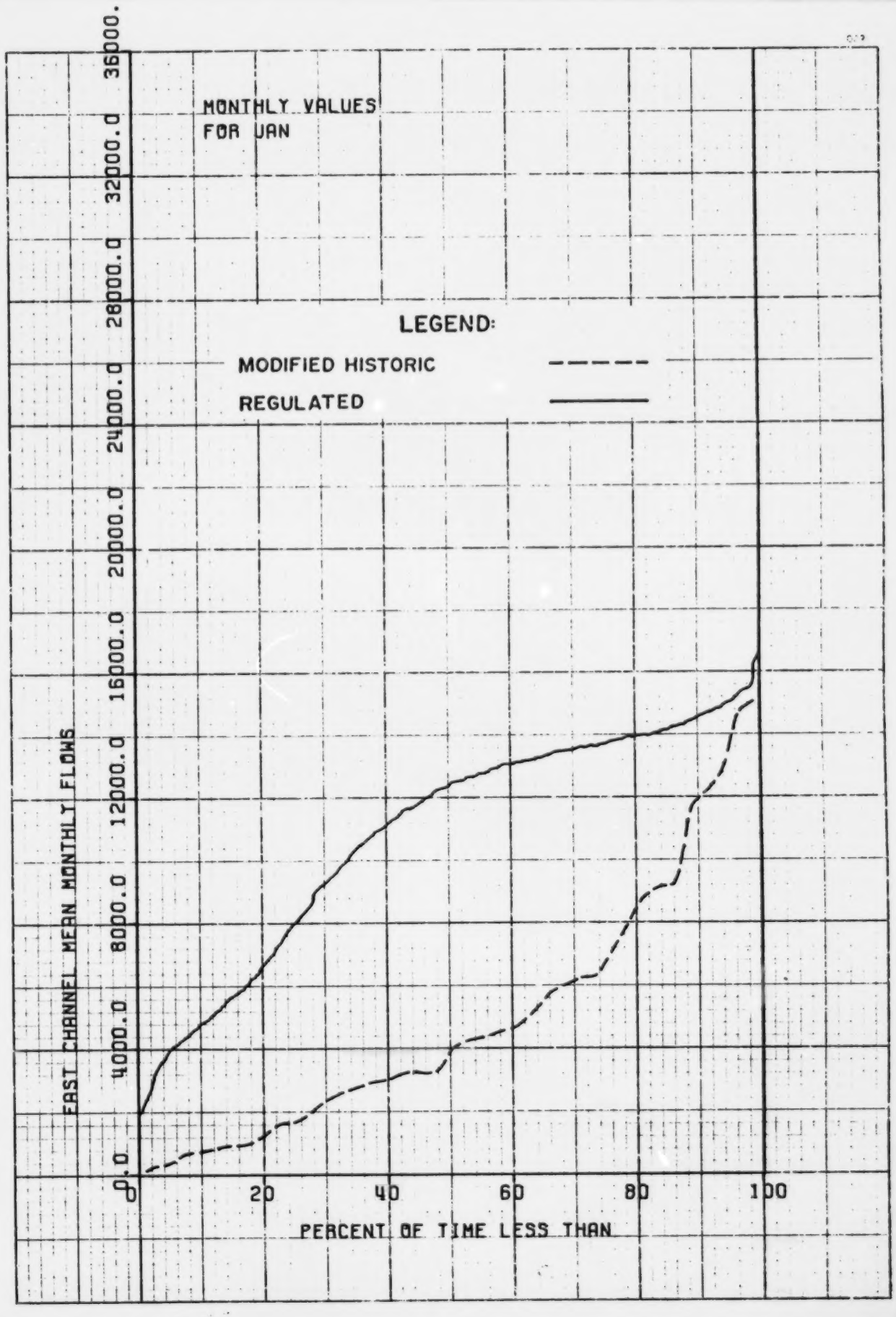
EAST CHANNEL - REGULATED CONDITIONS

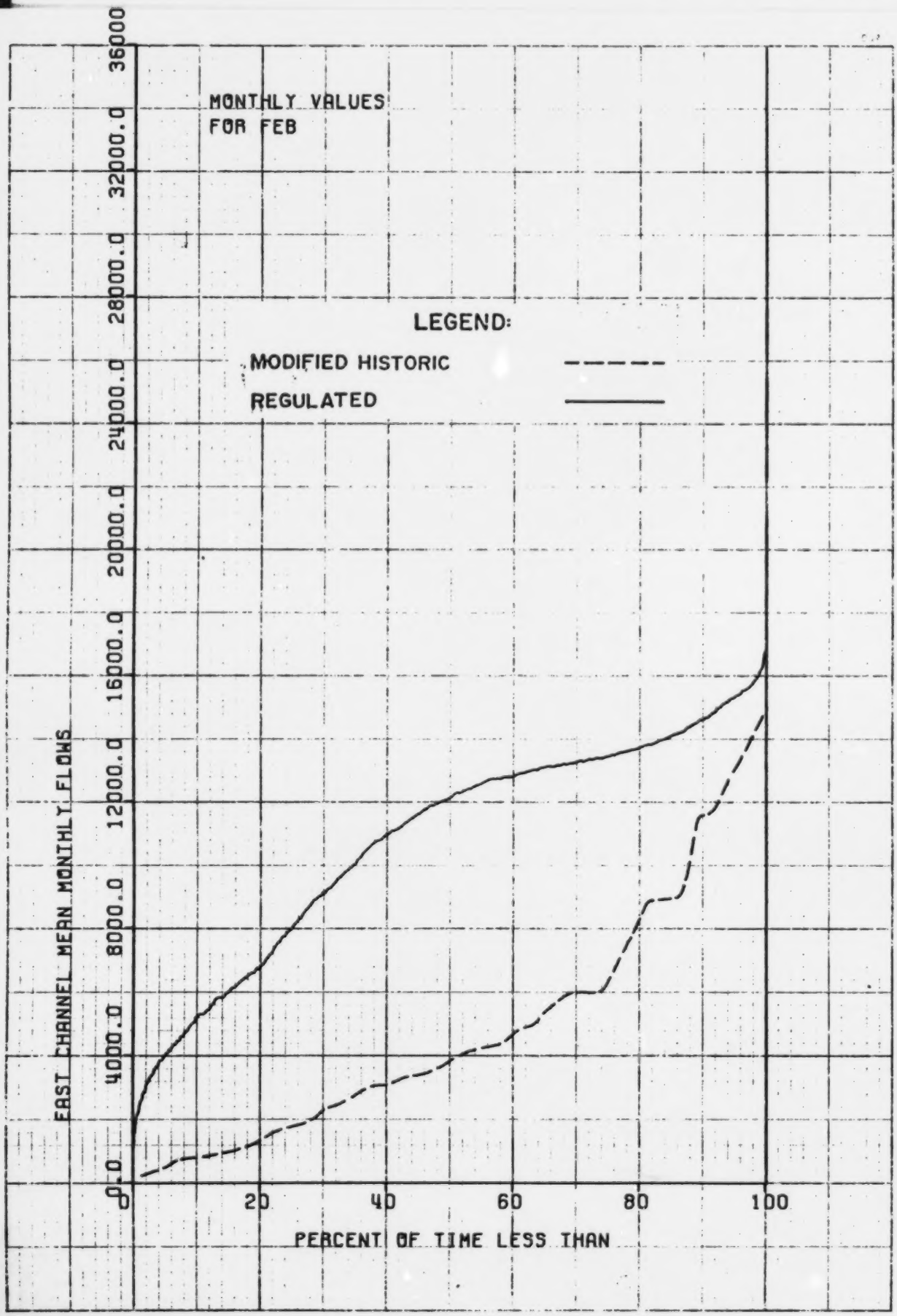
AVERAGE FLOW FLUCTUATIONS IN PERCENT

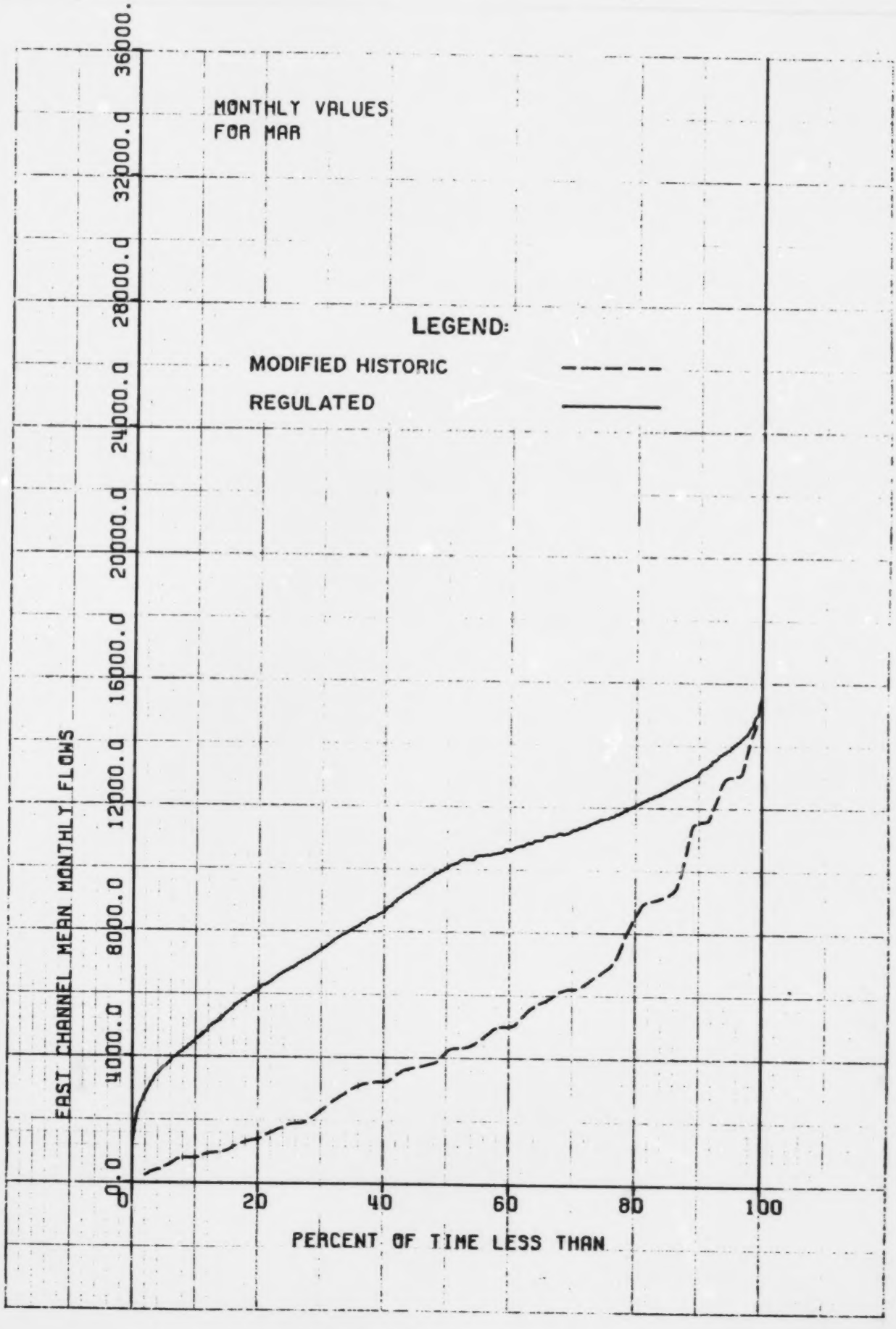
RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	6	50	43	51	9	16	34	18	0	0	28	17	38	17	42	18	37	34	33	41	3	0	10	16
1 - 2	0	37	4	1	2	24	28	10	0	0	24	6	24	4	25	4	9	14	1	18	0	0	16	22
2 - 4	0	7	1	0	0	49	10	0	1	0	21	3	14	1	10	1	1	5	0	6	0	10	4	32
4 - 6	0	0	0	0	0	0	0	0	20	0	1	0	2	0	0	0	0	0	0	1	0	47	0	0
6 - 8	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
8 -	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0

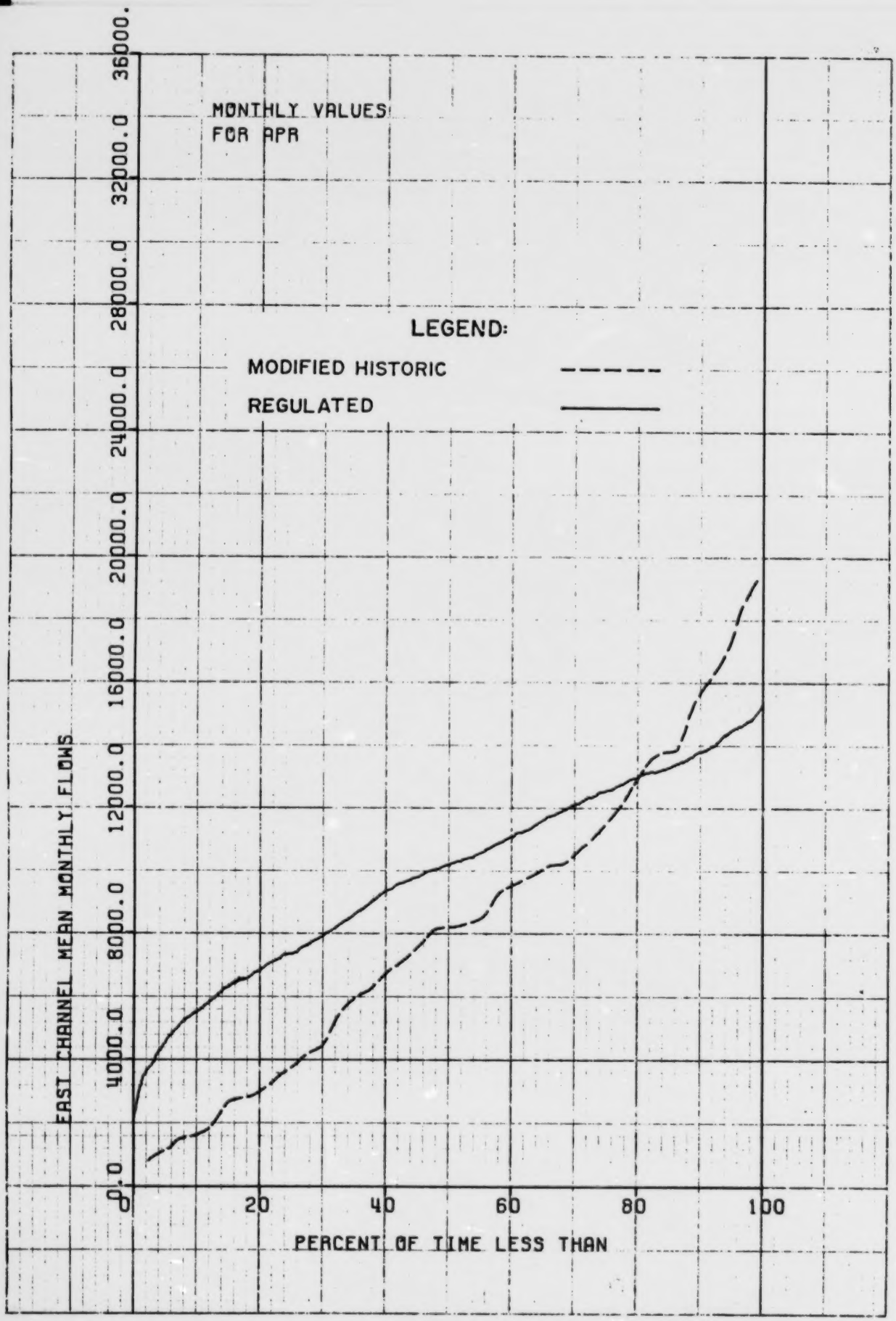
MEAN MONTHLY FLOWS IN CFS.

													ANNUAL
MINIMUM	700	1,300	1,400	2,400	7,800	7,700	8,900	8,100	6,100	5,300	1,000	2,800	700
AVERAGE	10,890	10,876	9,321	9,922	16,825	17,646	18,452	19,111	18,921	18,422	12,712	11,836	14,578
MAXIMUM	16,900	17,000	15,600	15,200	23,800	24,600	24,100	23,000	22,800	22,700	18,000	17,500	24,600


MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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12000.0
16000.0
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28000.0
32000.0
36000.
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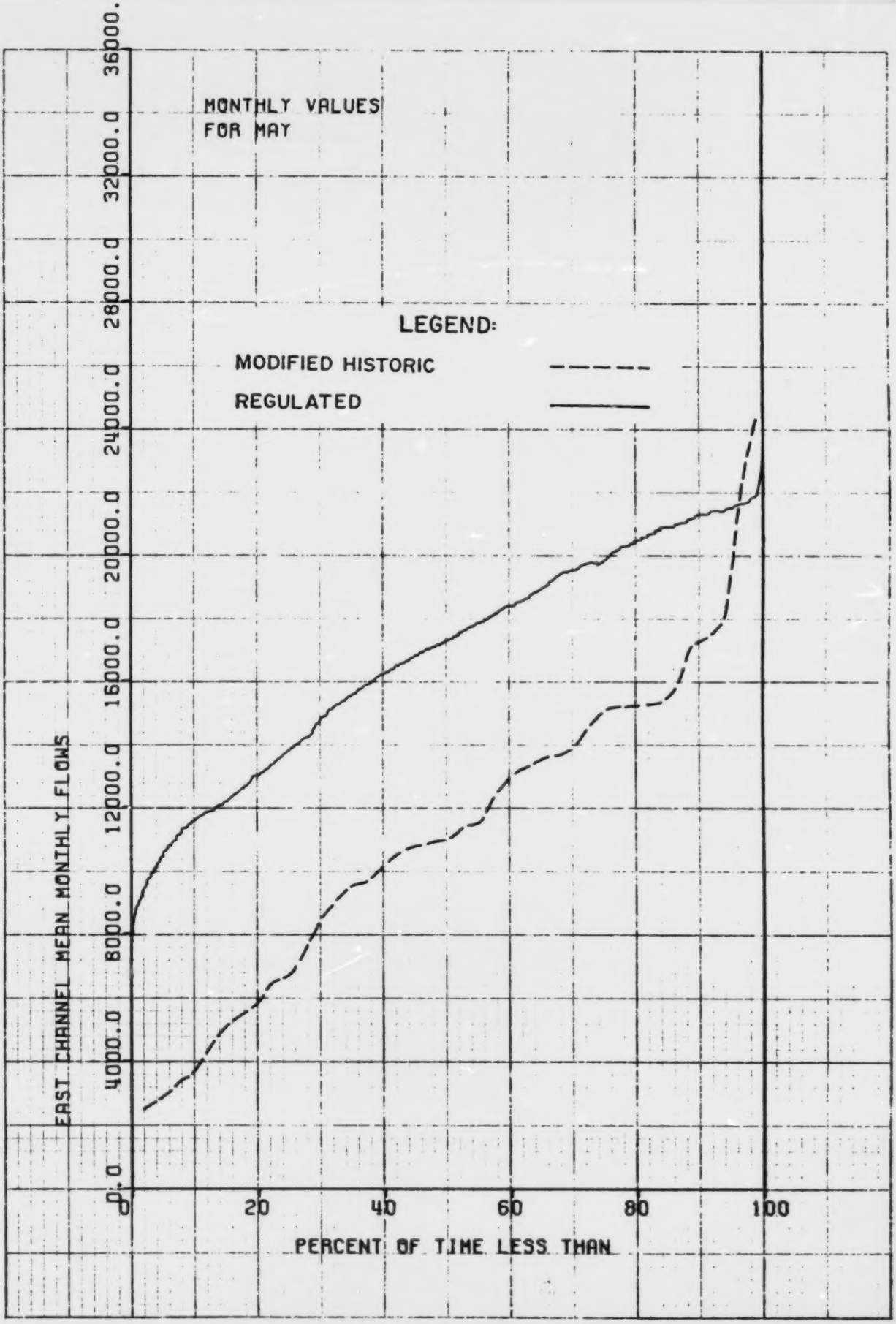
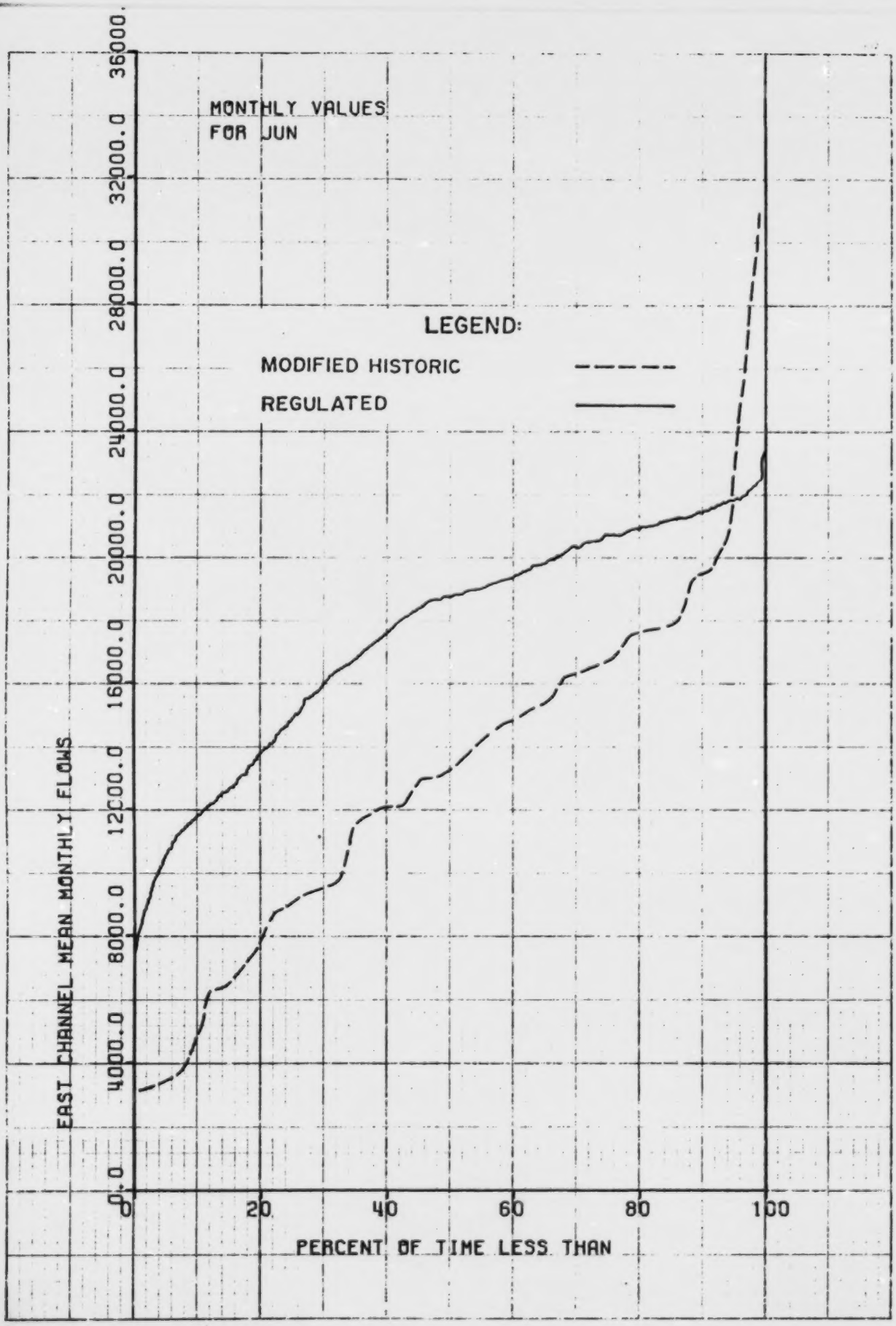
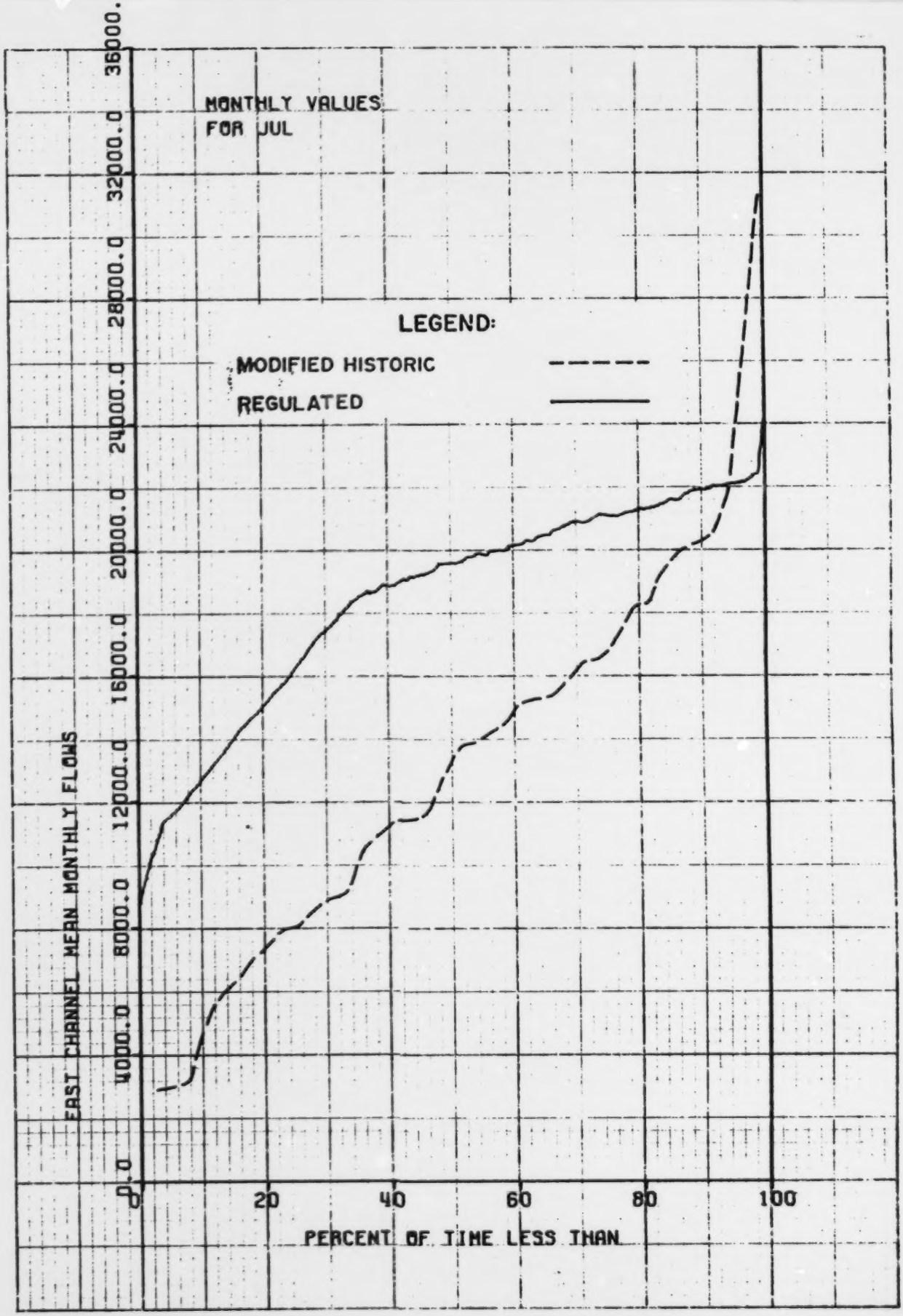
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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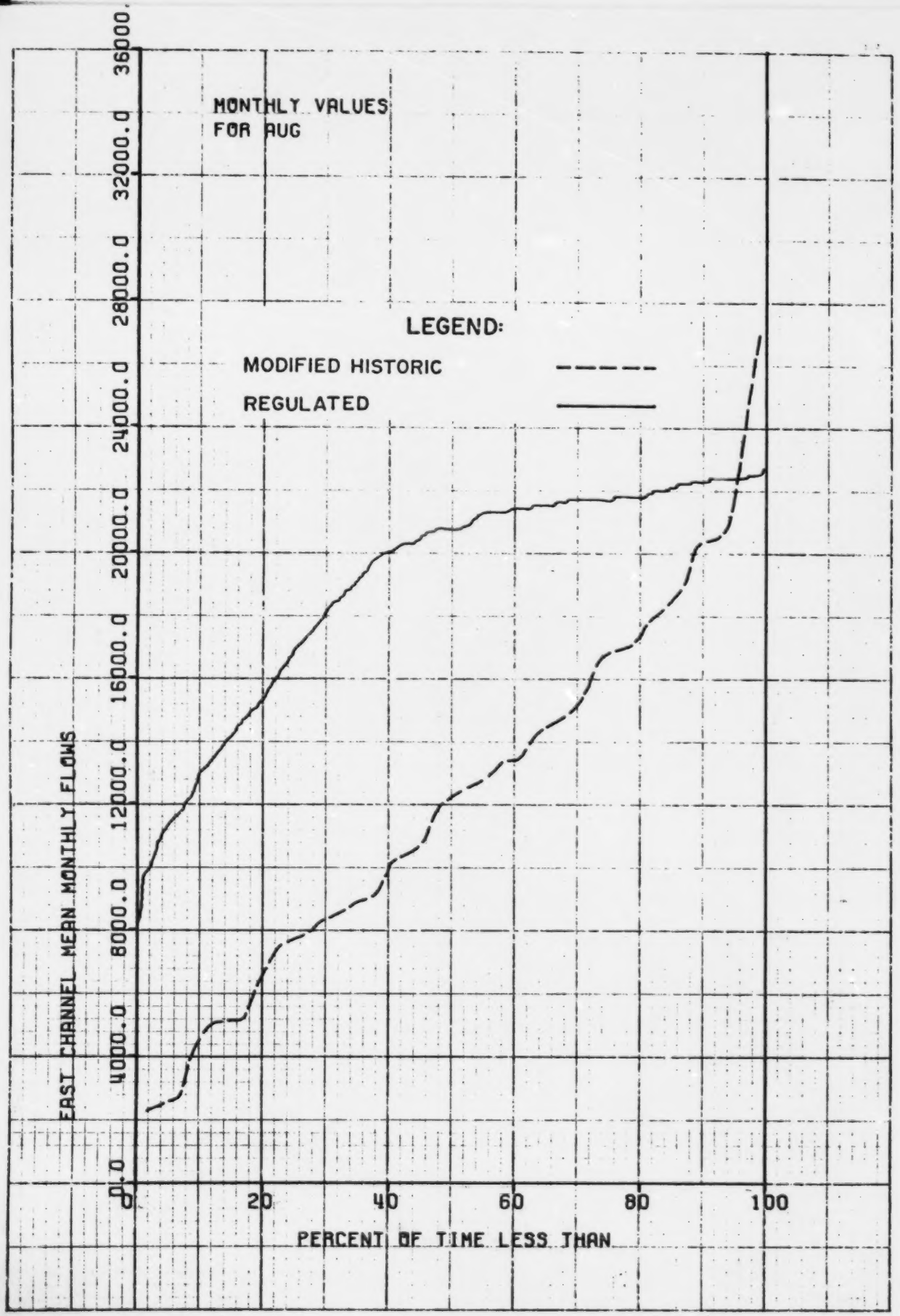
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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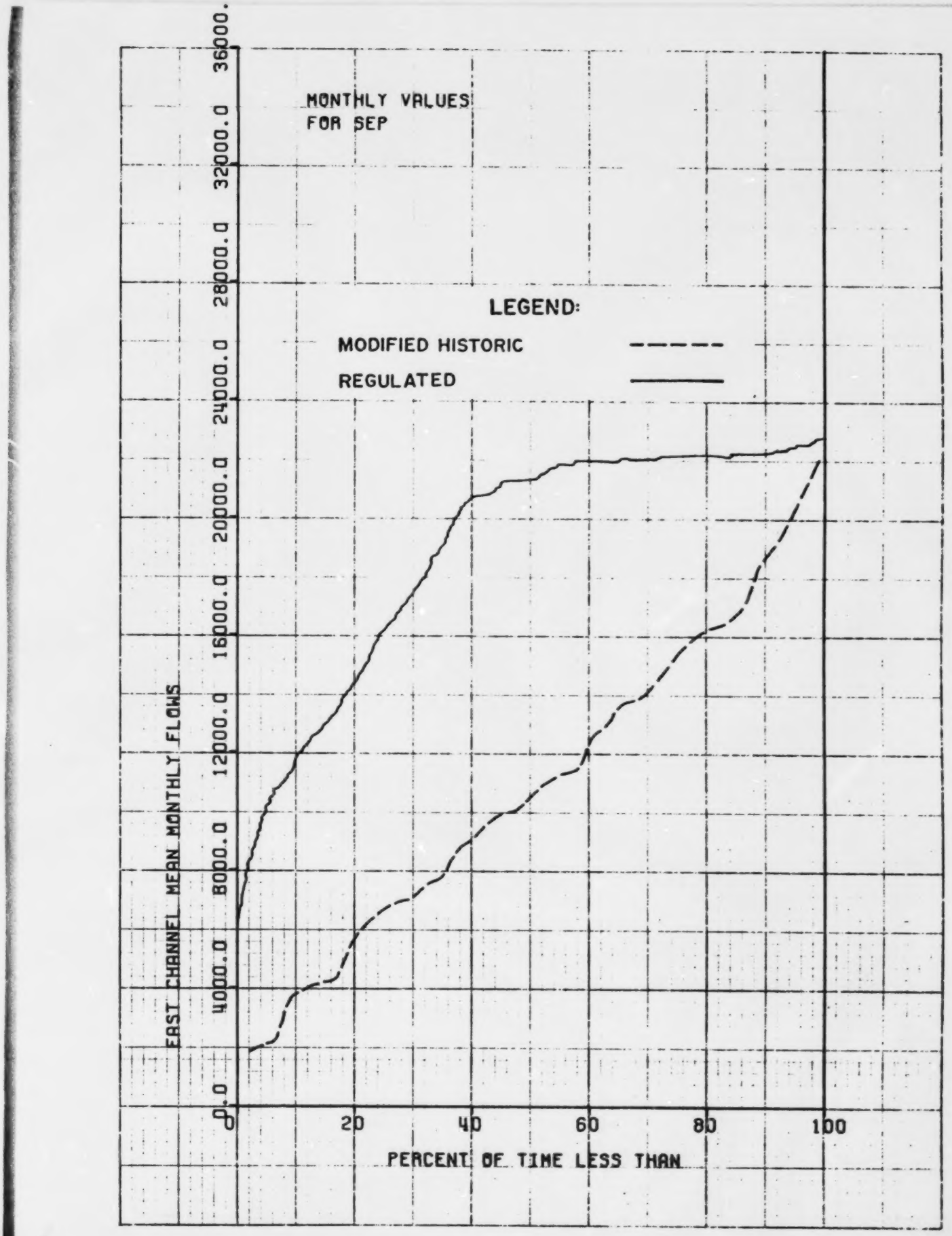
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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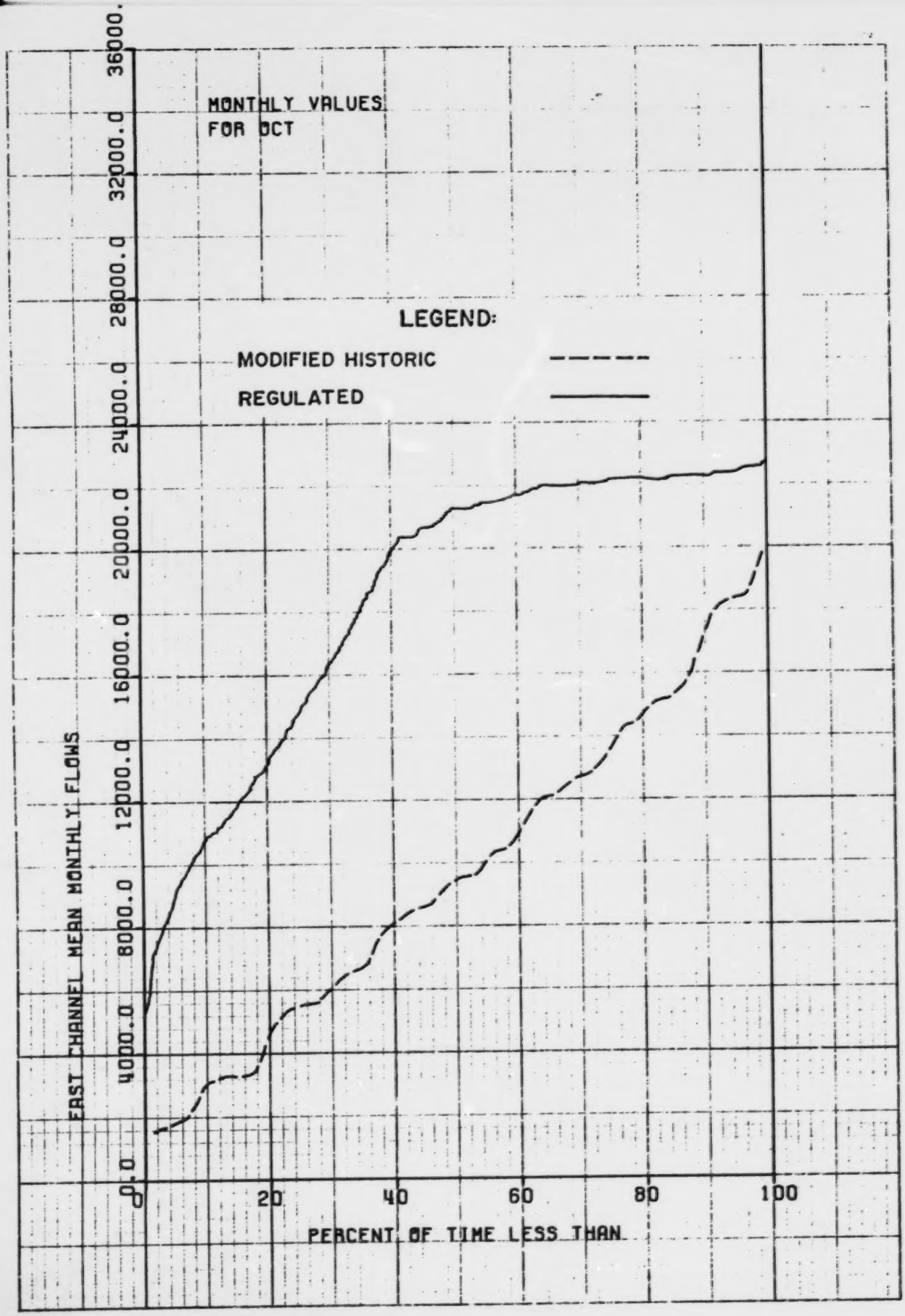
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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12000.0
16000.0
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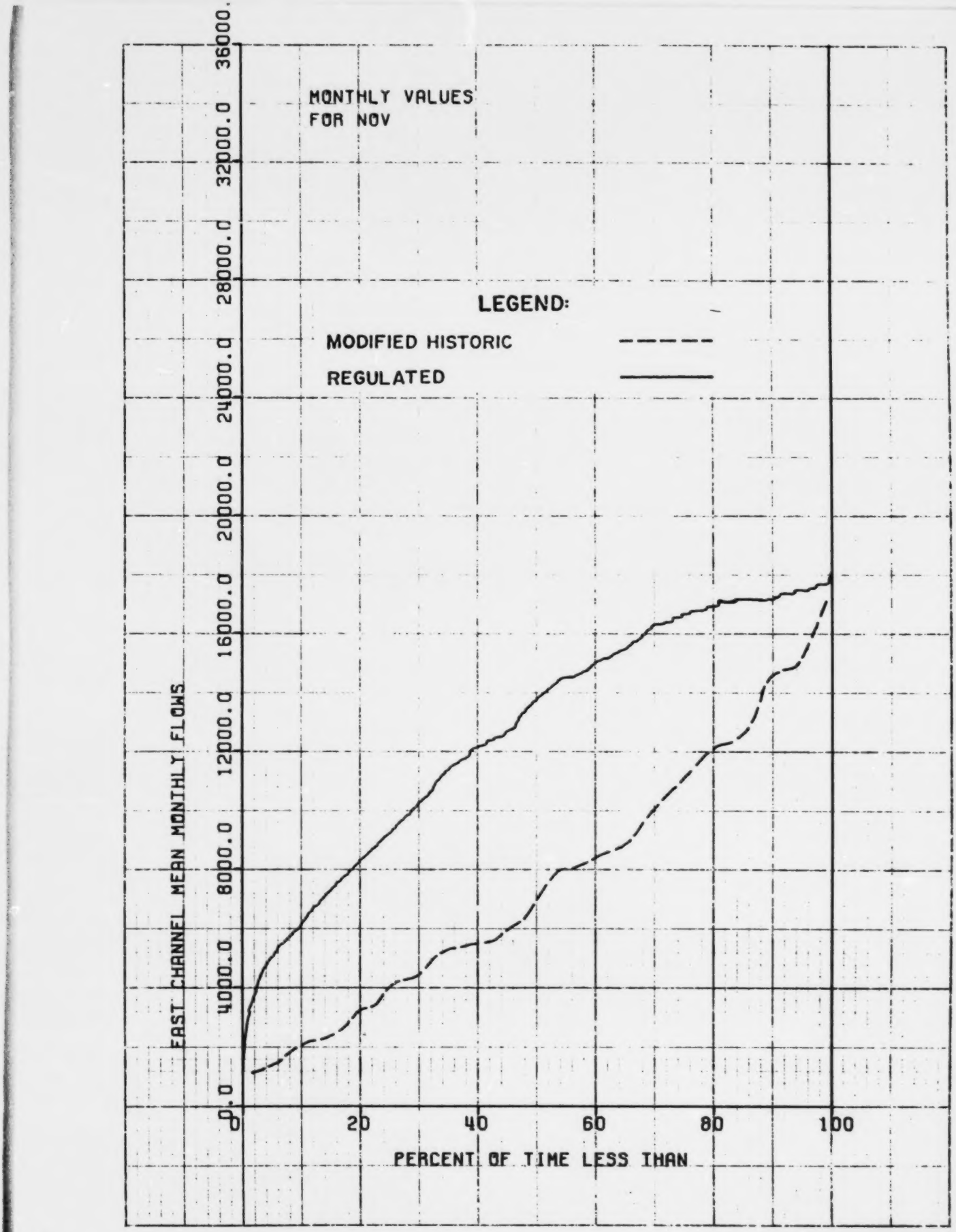
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
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8000.0
12000.0
16000.0
20000.0
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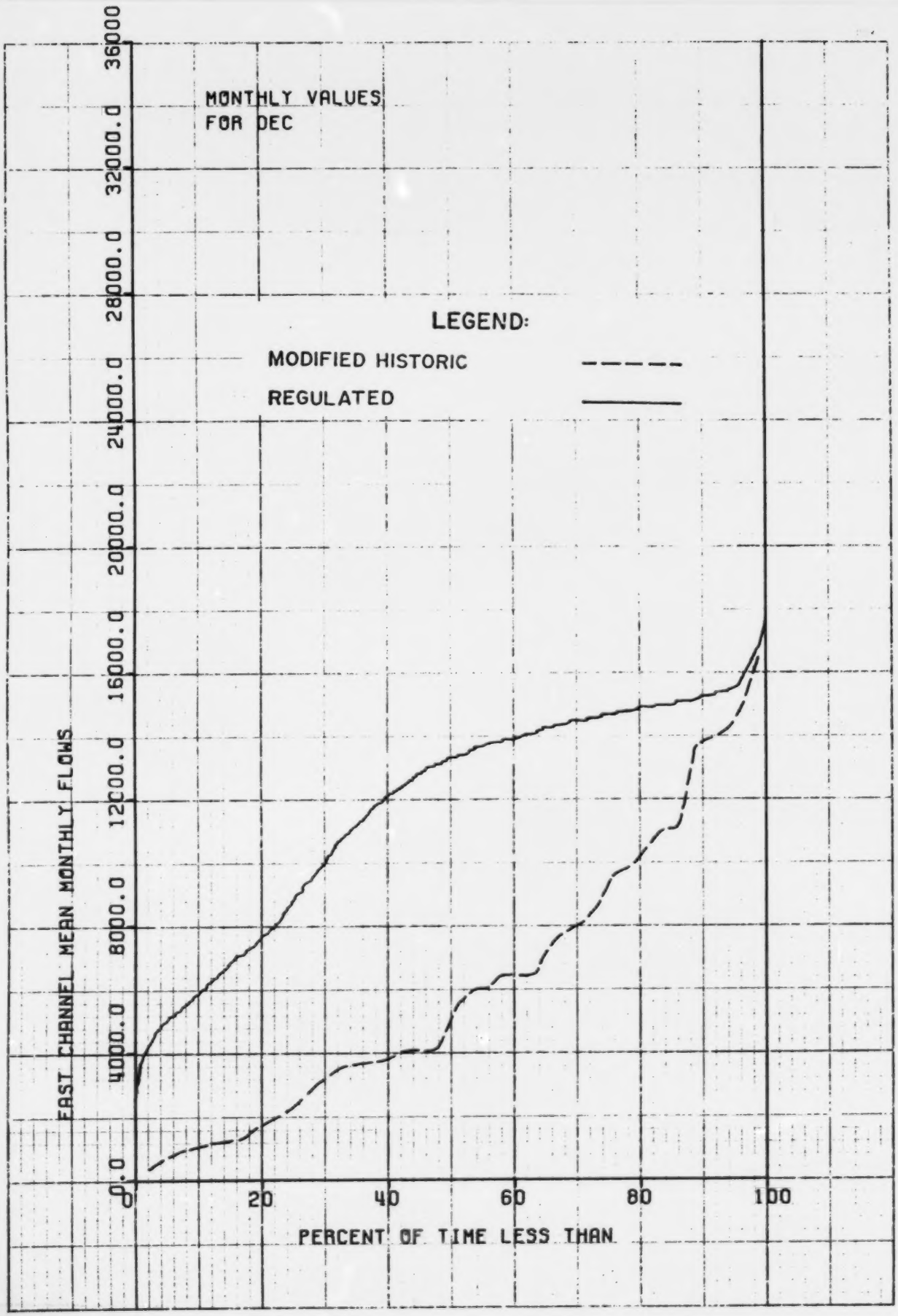
32000.0
36000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
EAST CHANNEL MEAN MONTHLY FLOWS
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
24000.0
28000.0
32000.0
36000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

NELSON RIVER (WEST CHANNEL)
FLOWS

WEST CHANNEL - MODIFIED HISTORIC CONDITIONS (Revised Oct./74)

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	3	95	45	55	97	3	0	0	0	0	61	3	32	61	11	87	3	84	0	89	3	34	0	0
5 - 10	0	3	0	0	0	0	89	0	0	0	29	0	8	0	0	3	0	13	0	11	0	63	0	0
10 - 20	0	0	0	0	0	0	11	0	95	0	8	0	0	0	0	0	0	0	0	0	0	0	0	100
20 - 30	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

MINIMUM	16,135	16,750	18,225	27,230	45,560	49,755	48,780	45,260	41,180	38,415	33,155	19,770	ANNUAL 16,135
AVERAGE	45,915	45,745	46,655	54,635	69,740	74,515	74,510	72,355	69,370	66,655	61,435	49,175	60,892
MAXIMUM	68,705	67,135	67,890	78,645	99,750	112,135	112,920	105,660	96,785	91,080	84,265	71,630	112,920

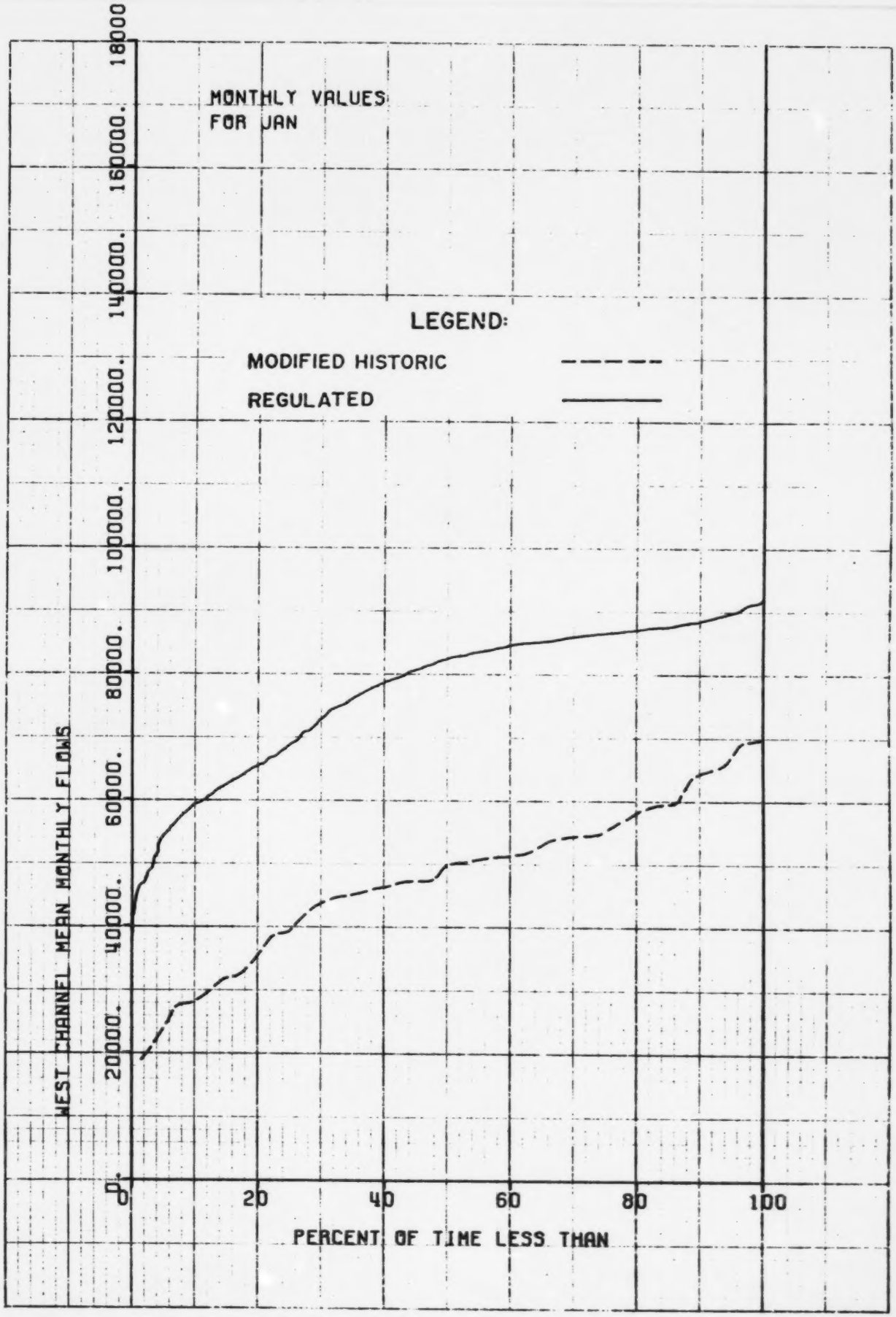
WEST CHANNEL - REGULATED CONDITIONS

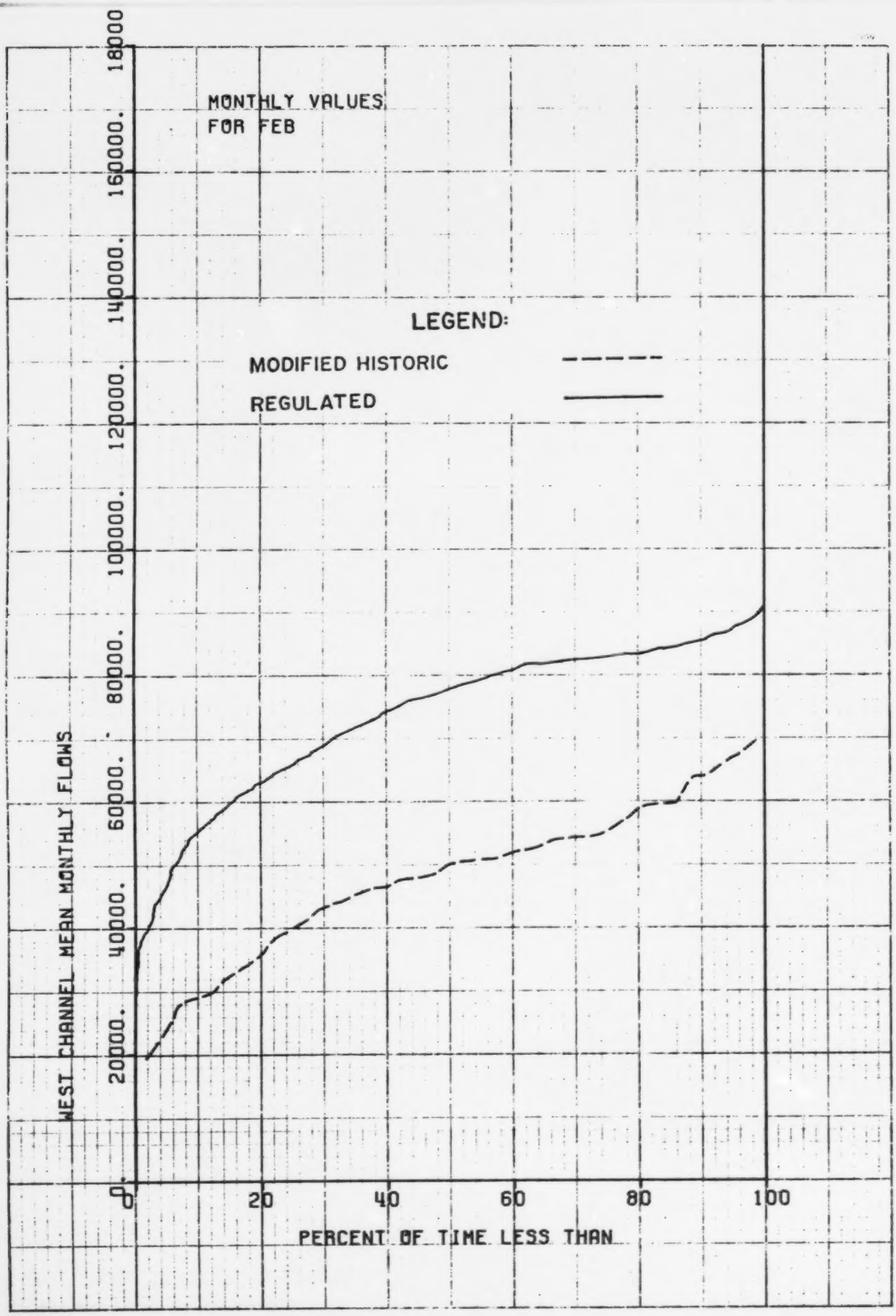
AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	3	56	2	84	1	57	15	18	3	4	5	6	19	19	17	12	9	10	14	8	8	3	5	6
5 - 10	5	28	0	7	1	9	2	11	3	7	3	12	3	12	13	5	17	5	14	6	7	2	6	6
10 - 20	7	1	0	5	0	17	3	23	6	24	11	22	4	9	6	6	26	5	22	14	25	6	12	4
20 - 30	0	0	0	2	0	9	2	17	12	17	12	4	3	7	2	13	3	11	4	9	13	1	10	15
30 - 40	0	0	0	0	0	5	0	8	8	5	4	2	3	3	2	3	2	5	1	2	7	2	15	6
40 -	0	0	0	0	0	1	0	1	7	4	13	6	10	8	3	18	2	5	4	2	26	0	15	0

MEAN MONTHLY FLOWS IN CFS.

MINIMUM	37,200	29,000	16,900	16,800	3,600	3,500	3,000	2,400	2,800	4,500	14,700	25,100	ANNUAL 2,400
AVERAGE	80,131	77,477	55,959	44,417	50,529	63,702	60,100	36,242	33,077	31,672	60,272	68,691	55,189
MAXIMUM	91,400	90,000	88,300	90,200	130,600	158,700	157,200	152,800	144,500	133,000	131,500	96,900	158,700


MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
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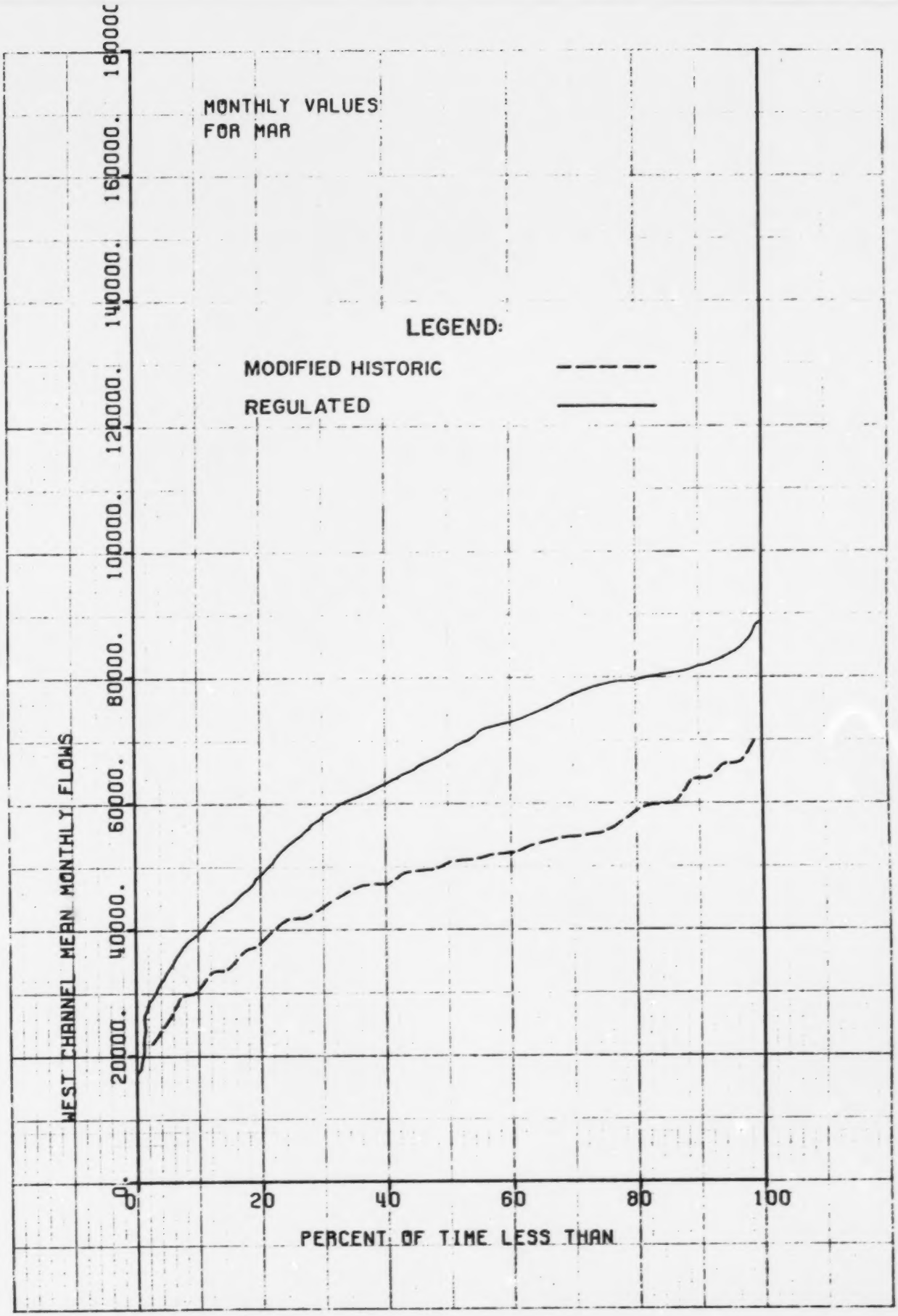
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
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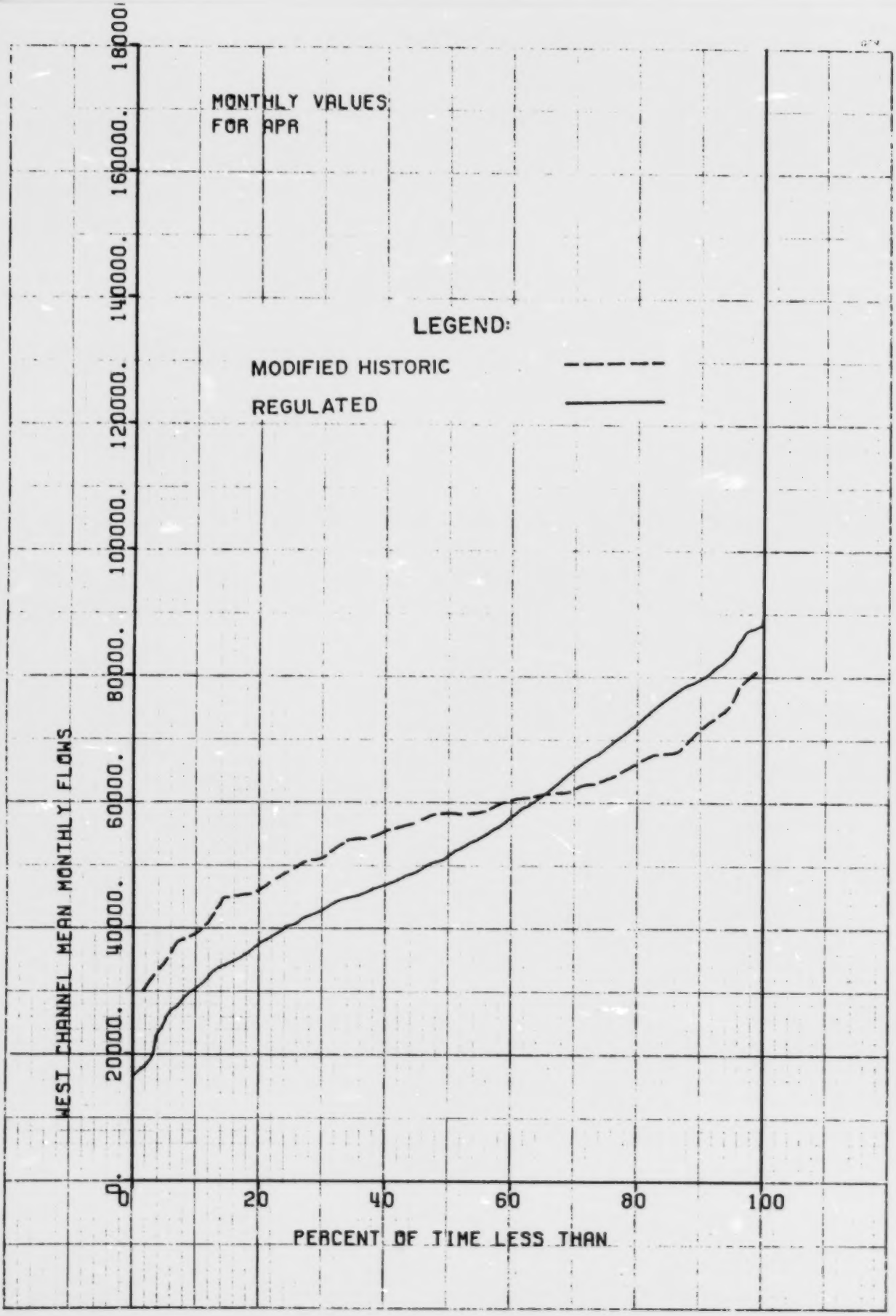
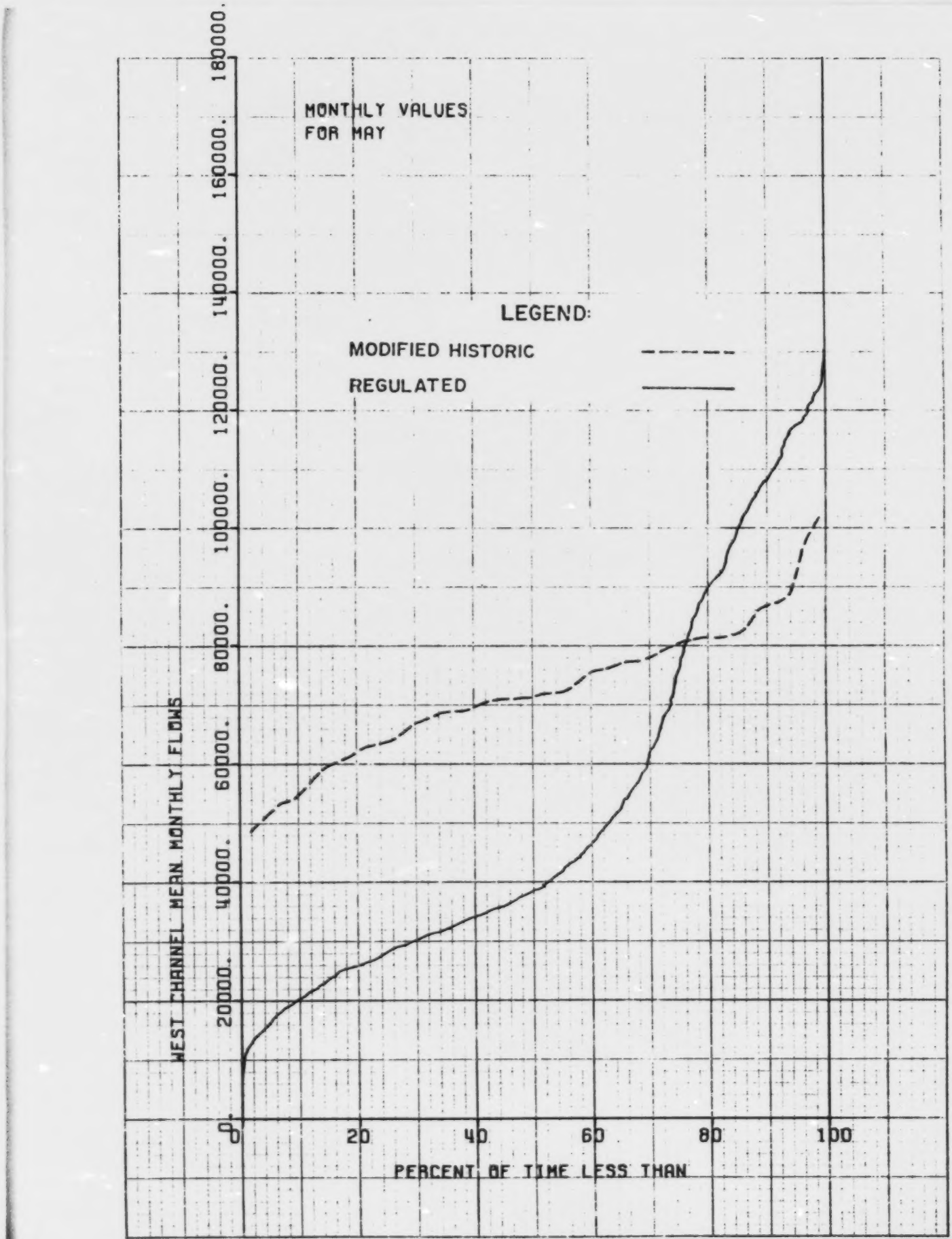
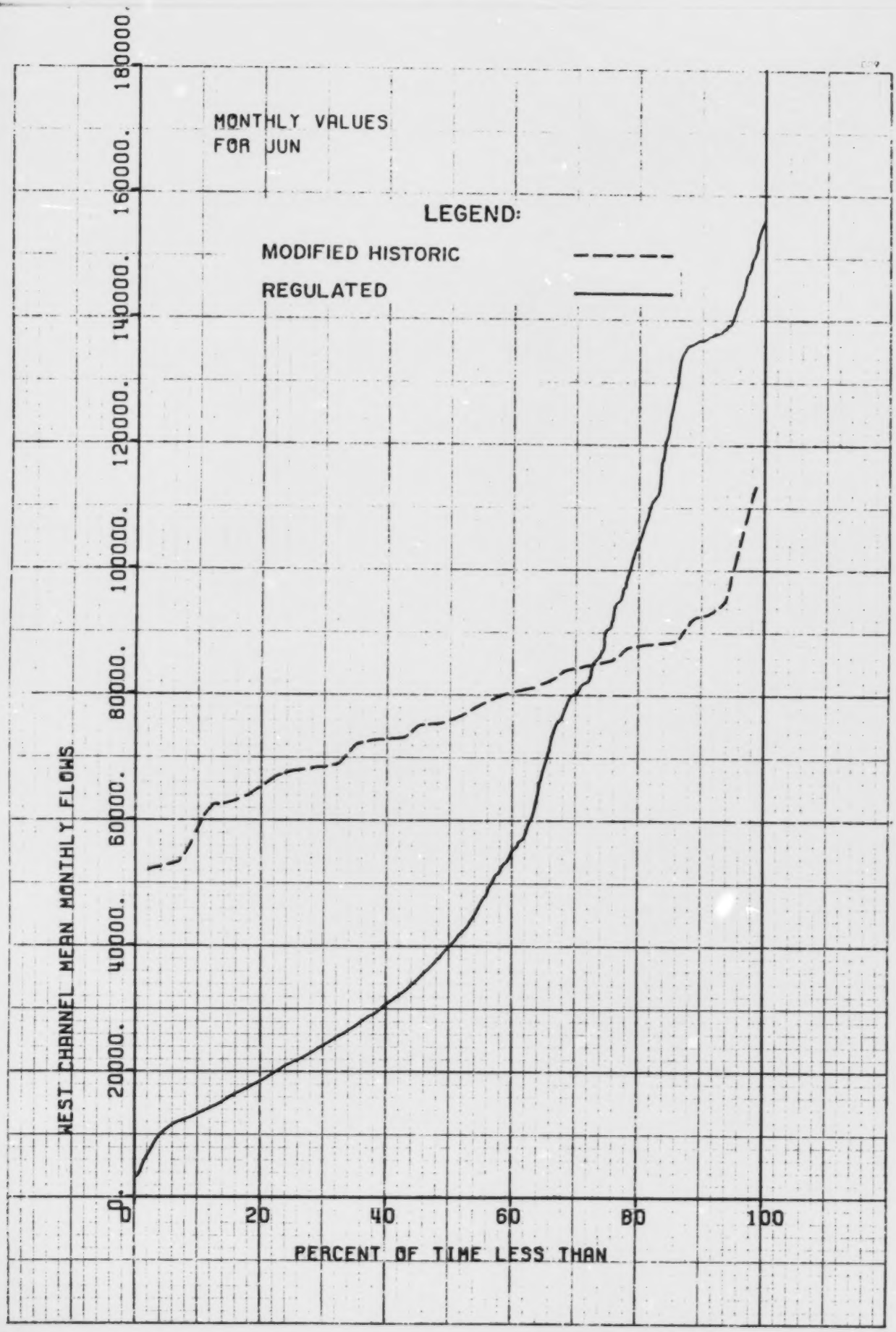
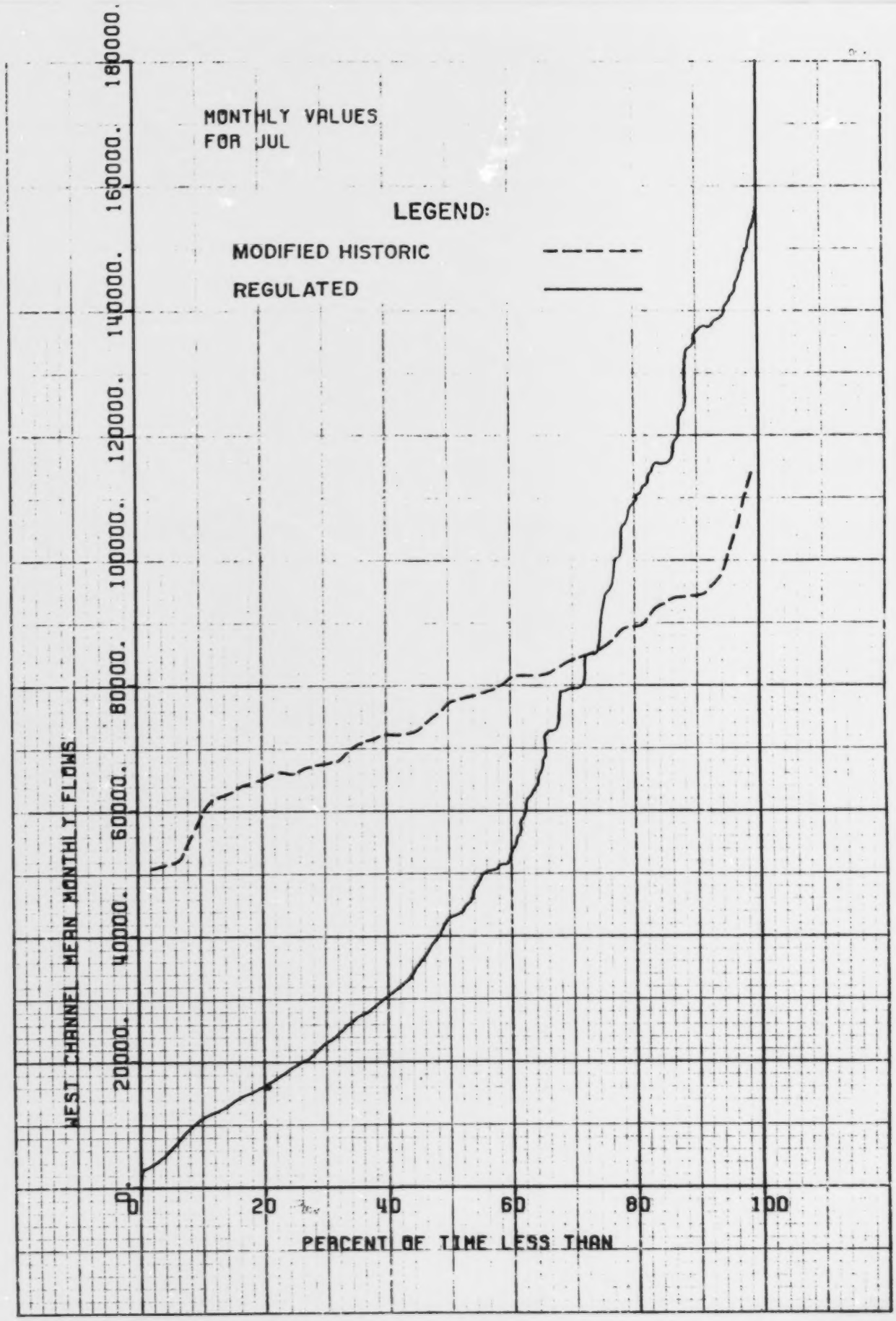
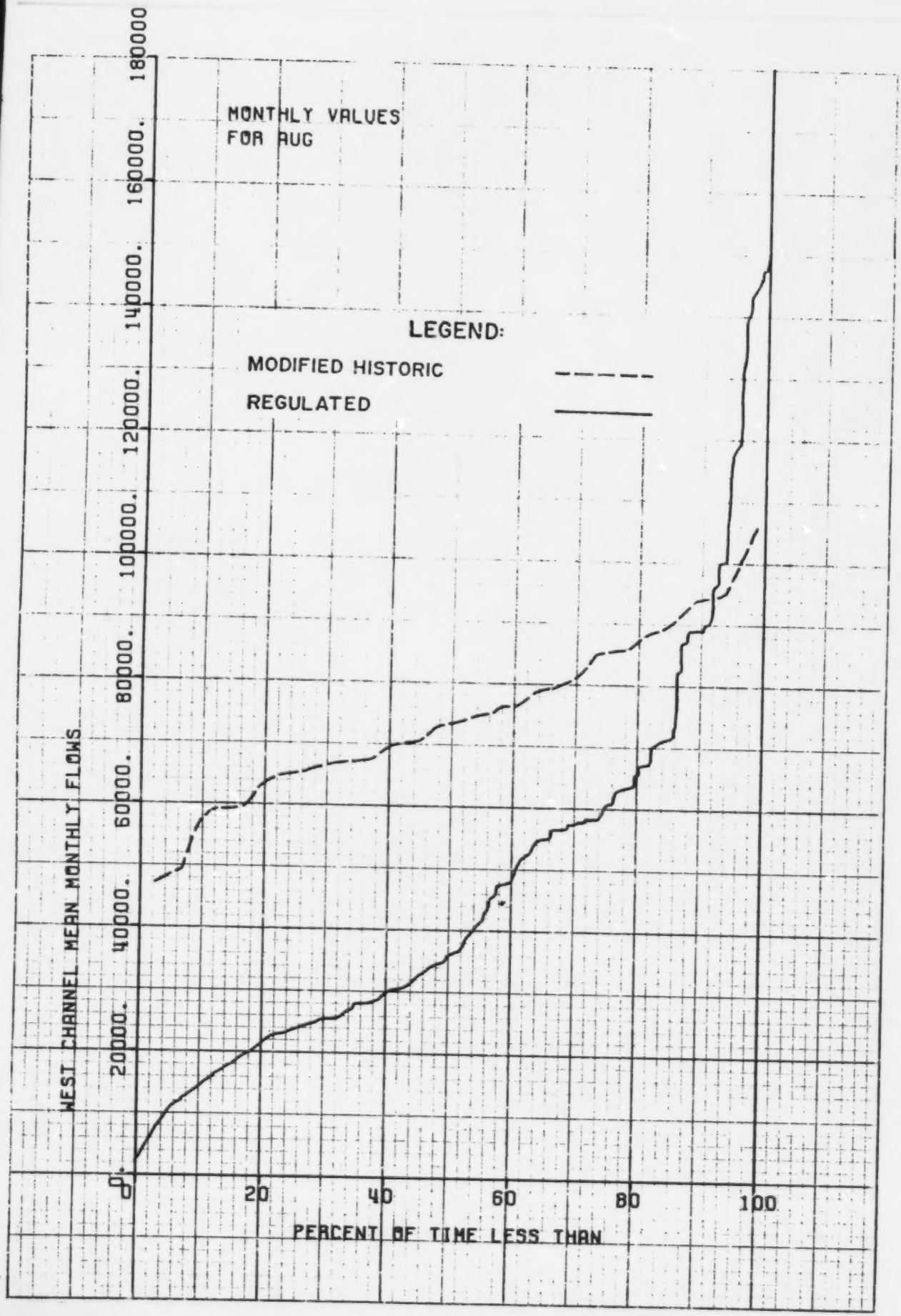
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
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100000.
120000.
140000.
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180000
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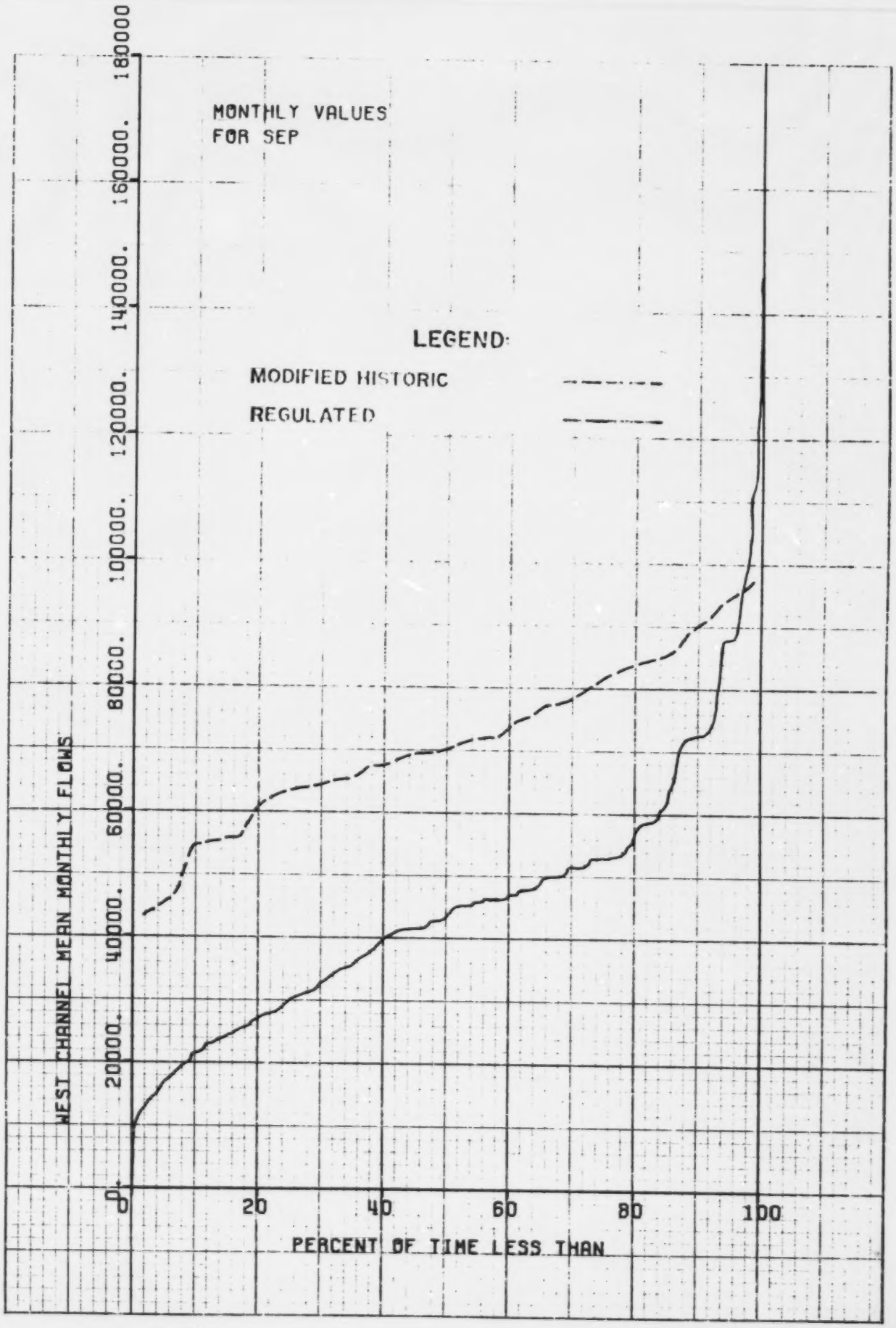
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
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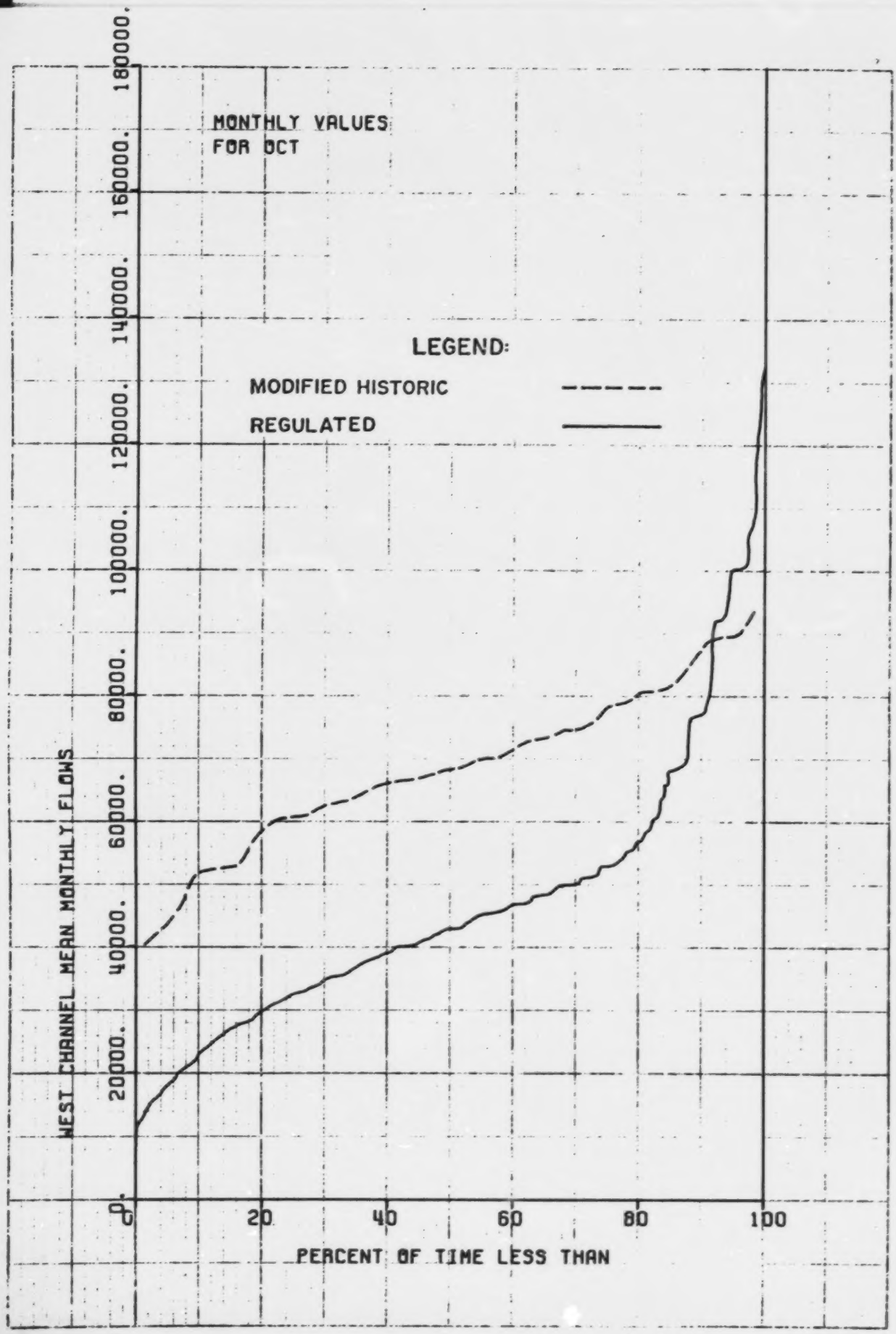
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
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180000.
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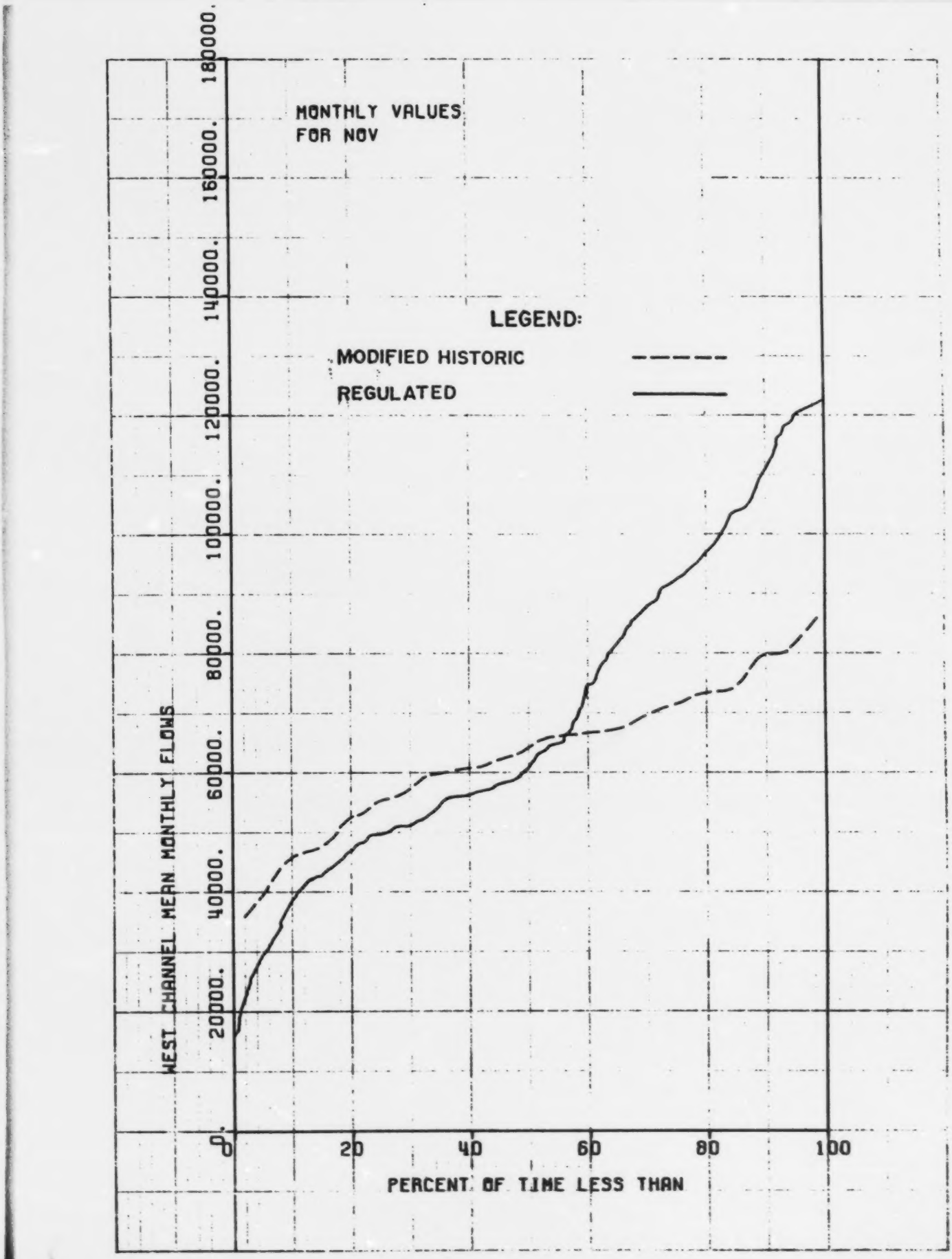
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
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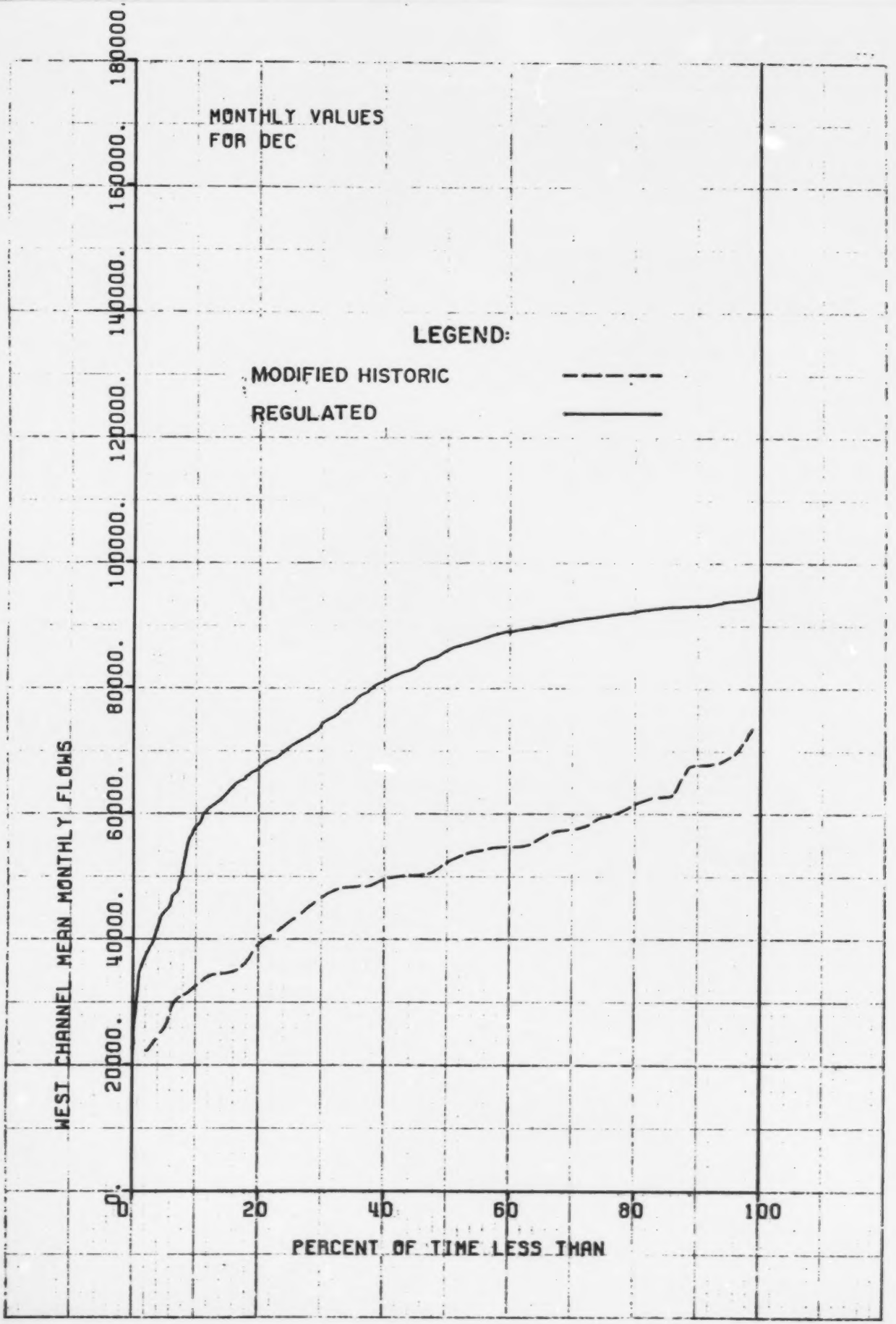
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
WEST CHANNEL MEAN MONTHLY FLOWS
0.
20000.
40000.
60000.
80000.
100000.
120000.
140000.
160000.
180000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

PLAYGREEN LAKE (SOUTH END)
LEVELS

LOWER PLAYGREEN LAKE–MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	3	97	45	55	97	3	42	0	32	68	95	3	37	63	11	89	3	97	0	100	3	97	84	16
1 - 2	0	0	0	0	0	0	58	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
2 - 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

													ANNUAL
MINIMUM	706.99	707.14	707.43	708.72	709.47	709.98	709.75	709.31	708.82	708.51	707.91	707.60	706.99
AVERAGE	711.18	711.17	711.31	712.38	712.22	712.69	712.67	712.44	712.12	711.82	711.22	711.59	711.90
MAXIMUM	713.98	713.89	713.98	714.86	714.87	715.86	715.90	715.26	714.53	714.17	713.57	714.28	715.90

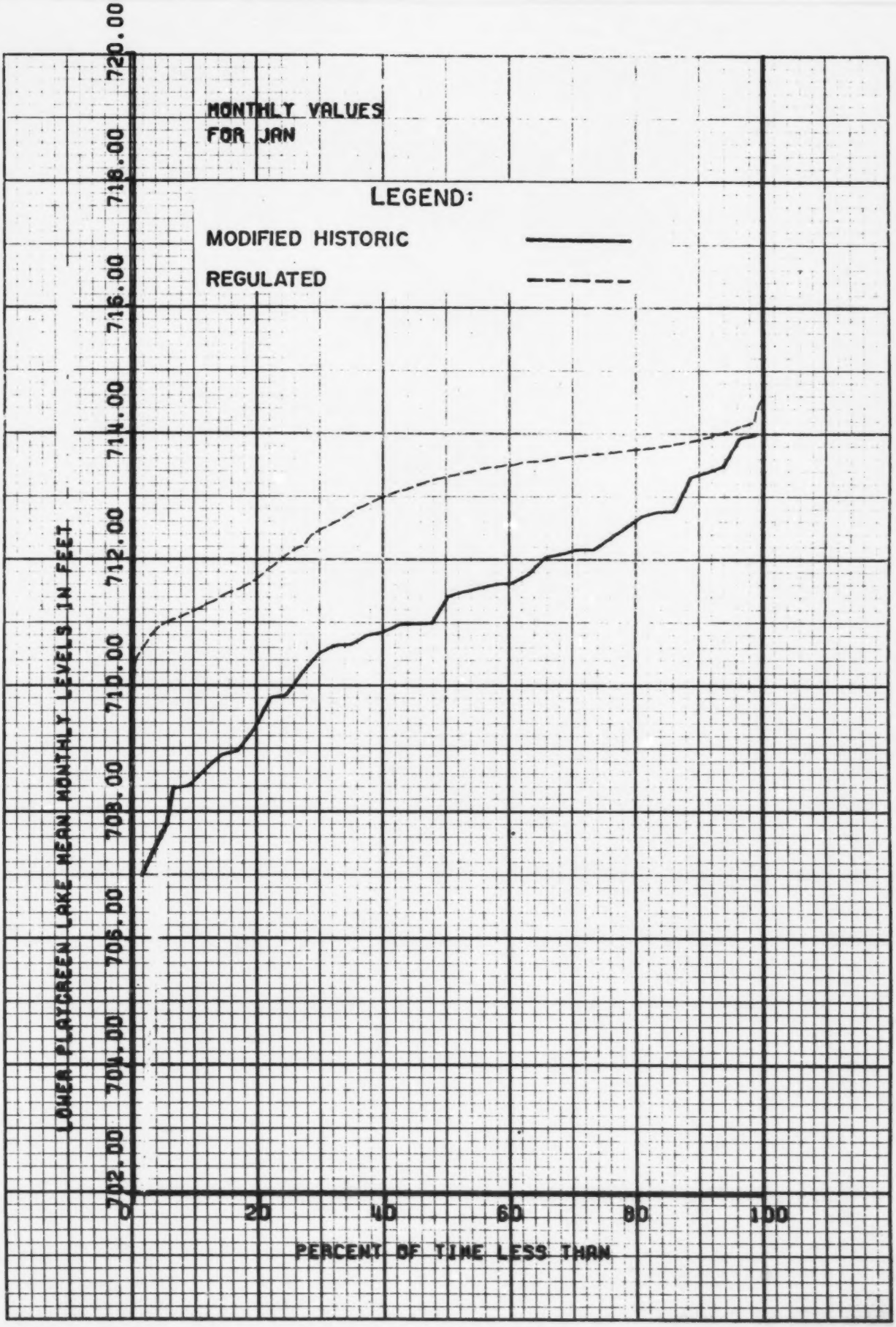
LOWER PLAYGREEN LAKE - REGULATED CONDITIONS

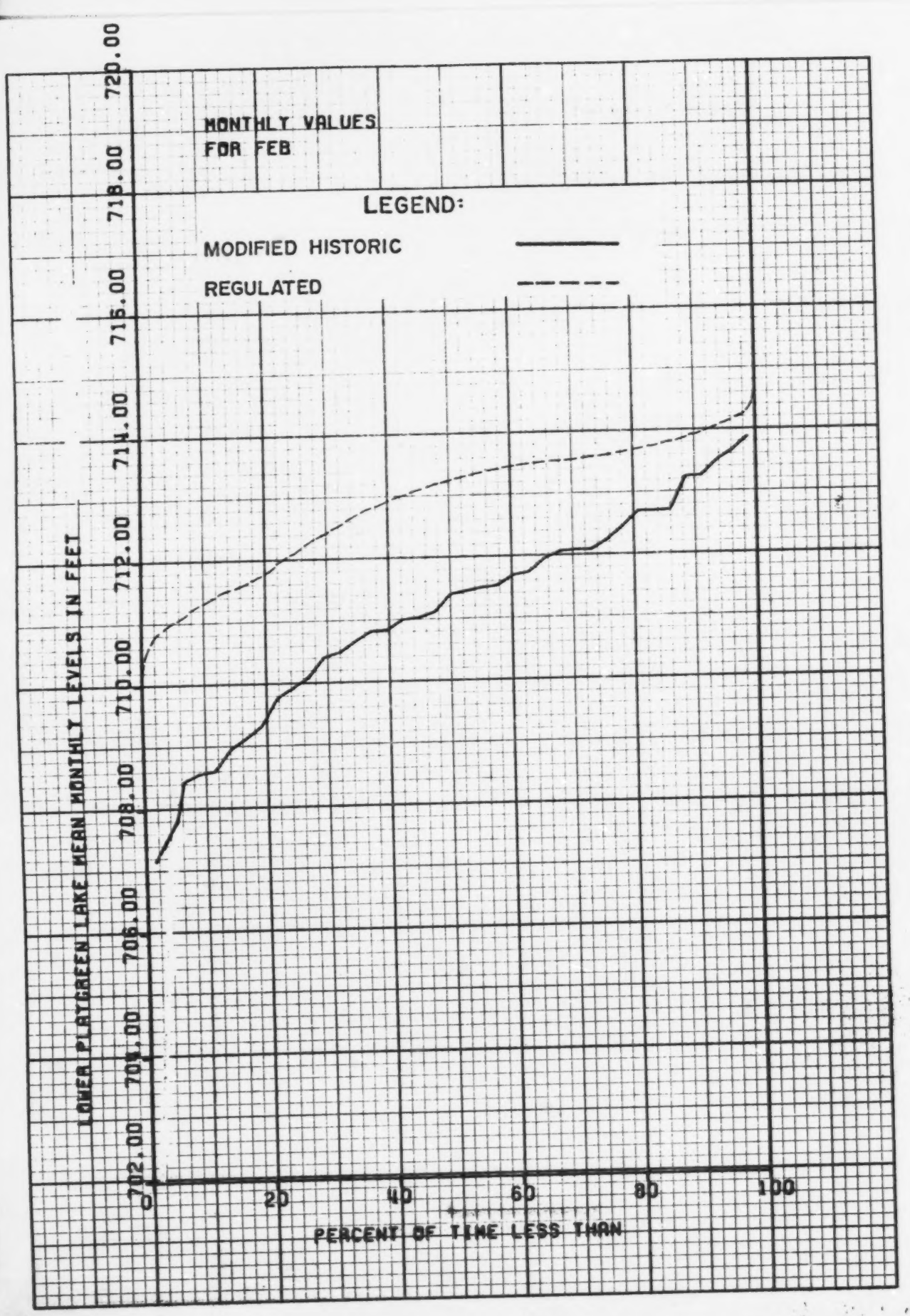
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

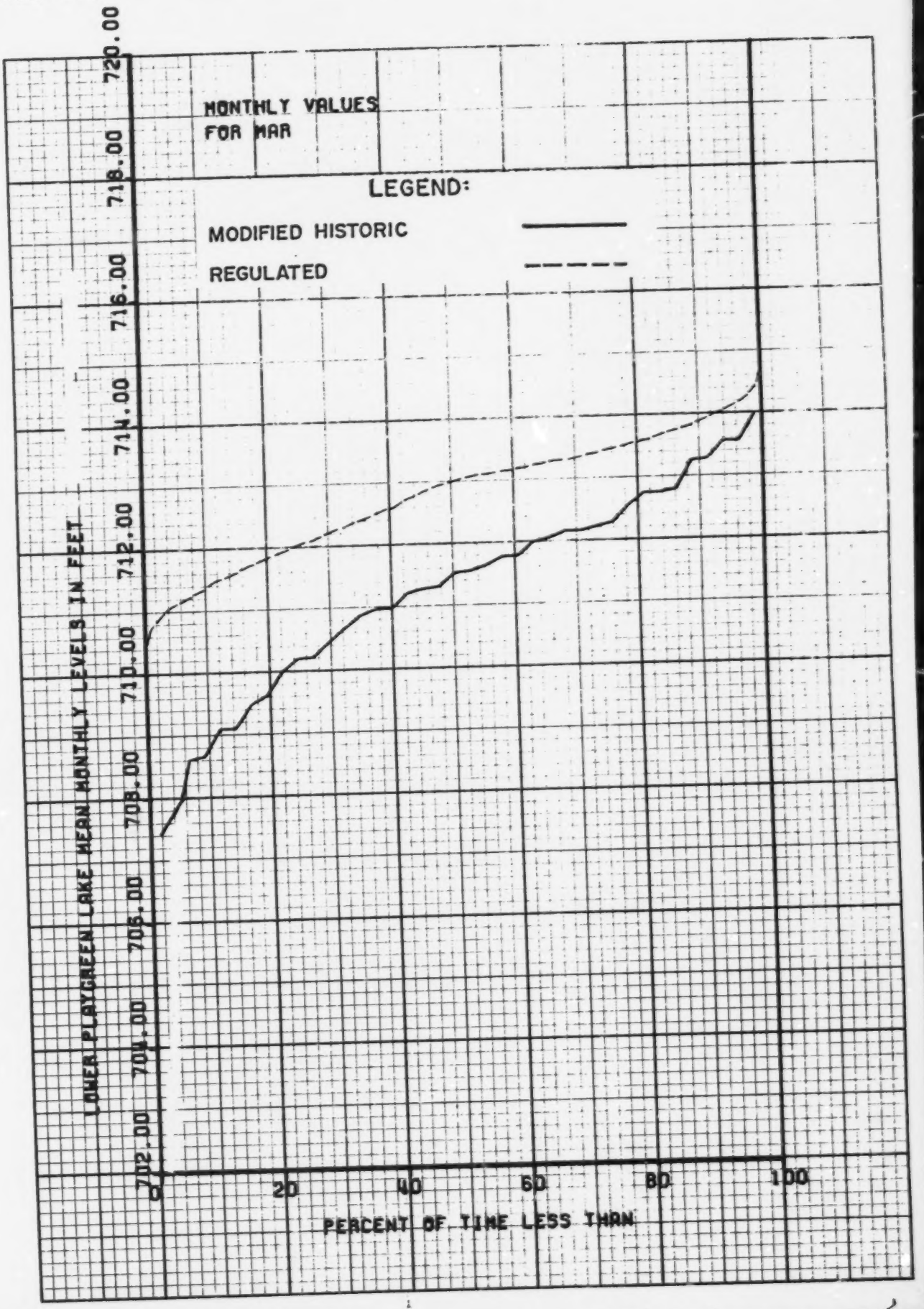
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	5	95	44	56	31	69	72	28	88	4	72	27	75	23	77	23	46	54	32	67	11	66	29	71
1 - 2	0	0	0	0	0	0	0	0	8	0	1	0	2	0	0	0	0	0	0	1	0	23	0	0
2 - 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

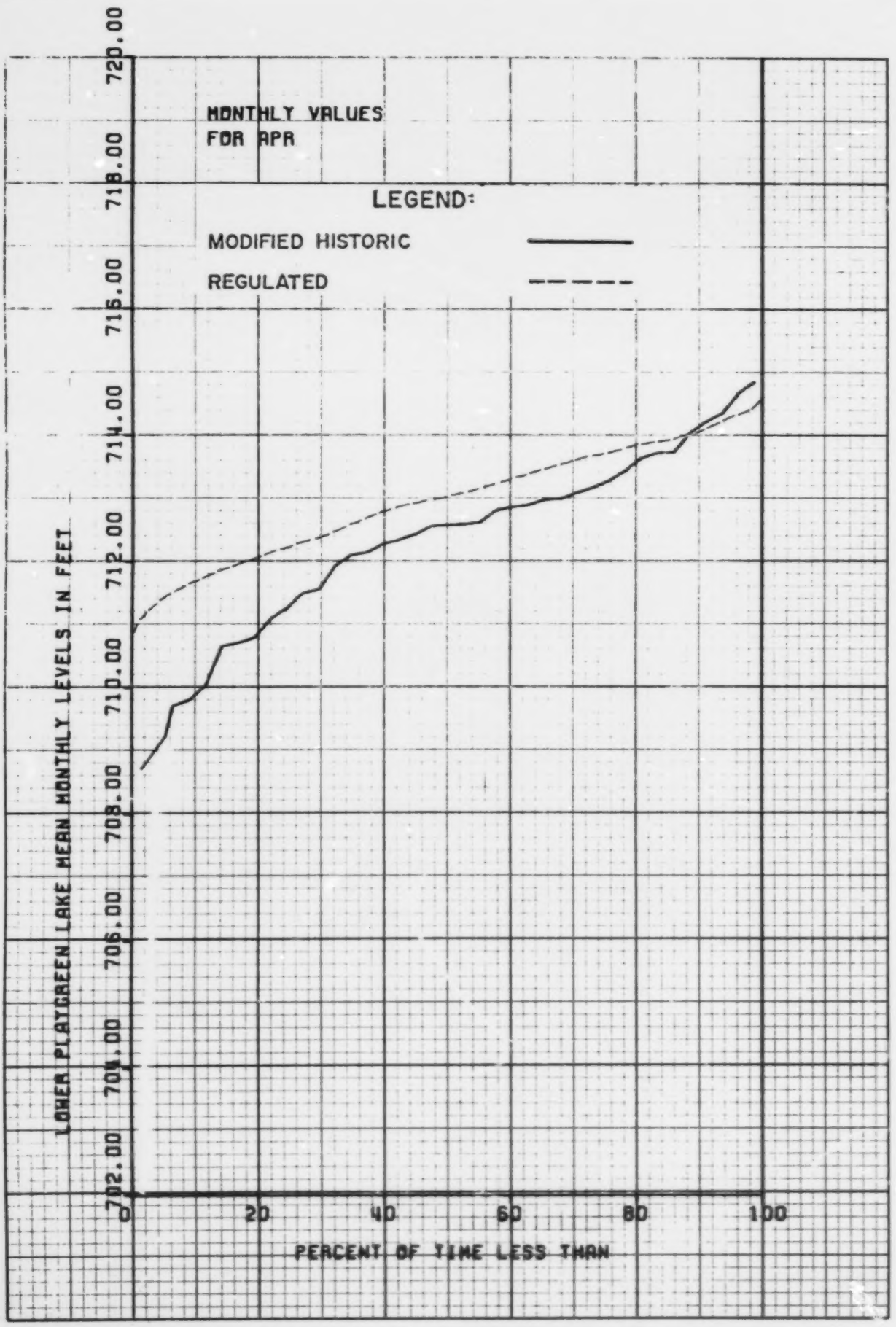
MEAN MONTHLY LEVELS IN FEET

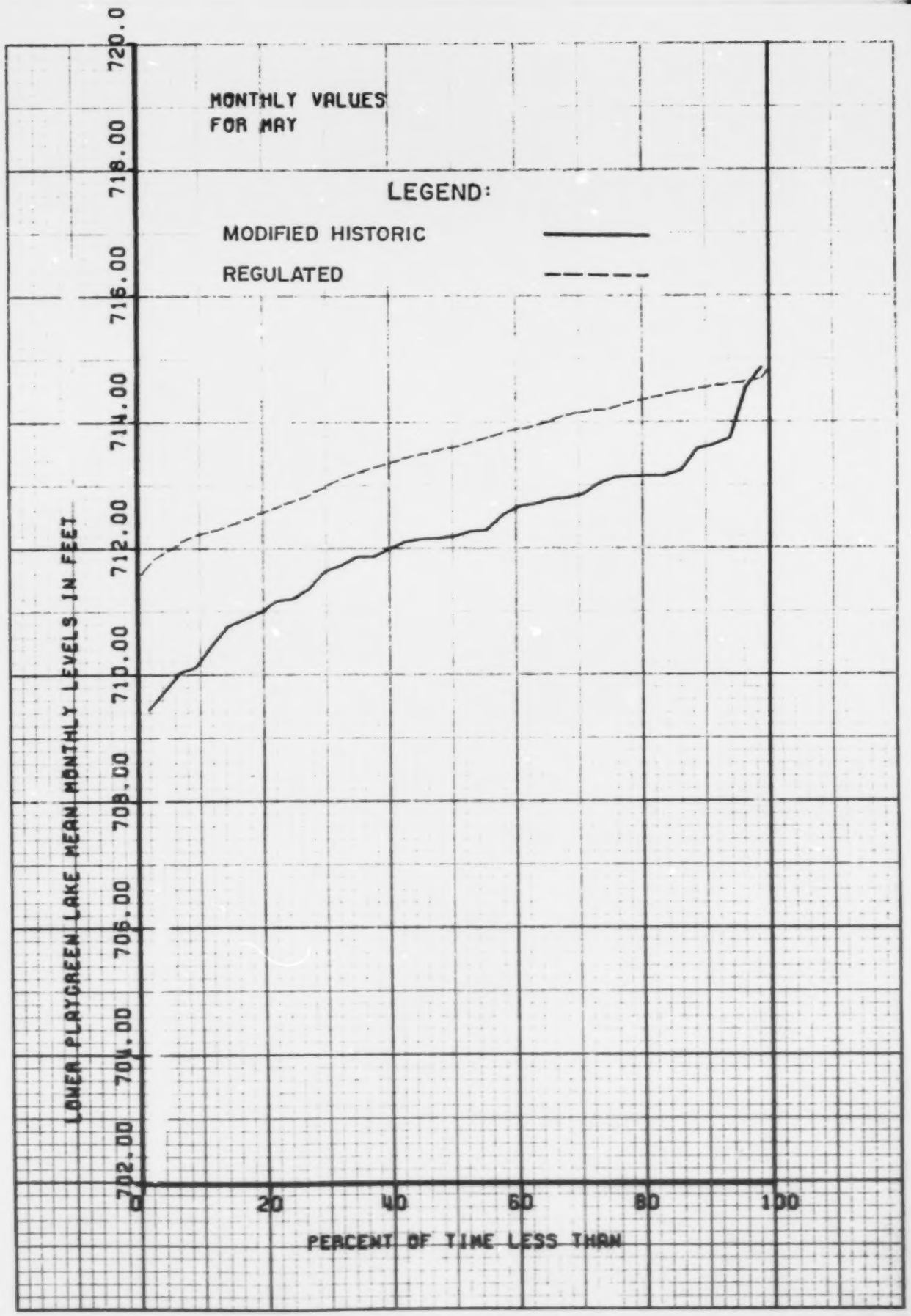
													ANNUAL
MINIMUM	710.06	710.22	710.40	710.71	711.30	711.27	711.55	711.36	710.88	710.69	710.13	710.64	710.06
AVERAGE	712.88	712.88	712.76	712.93	713.49	713.69	713.89	714.05	714.00	713.88	713.39	713.15	713.42
MAXIMUM	714.55	714.59	714.63	714.51	715.19	715.39	715.28	715.00	714.95	714.93	714.85	714.72	715.39

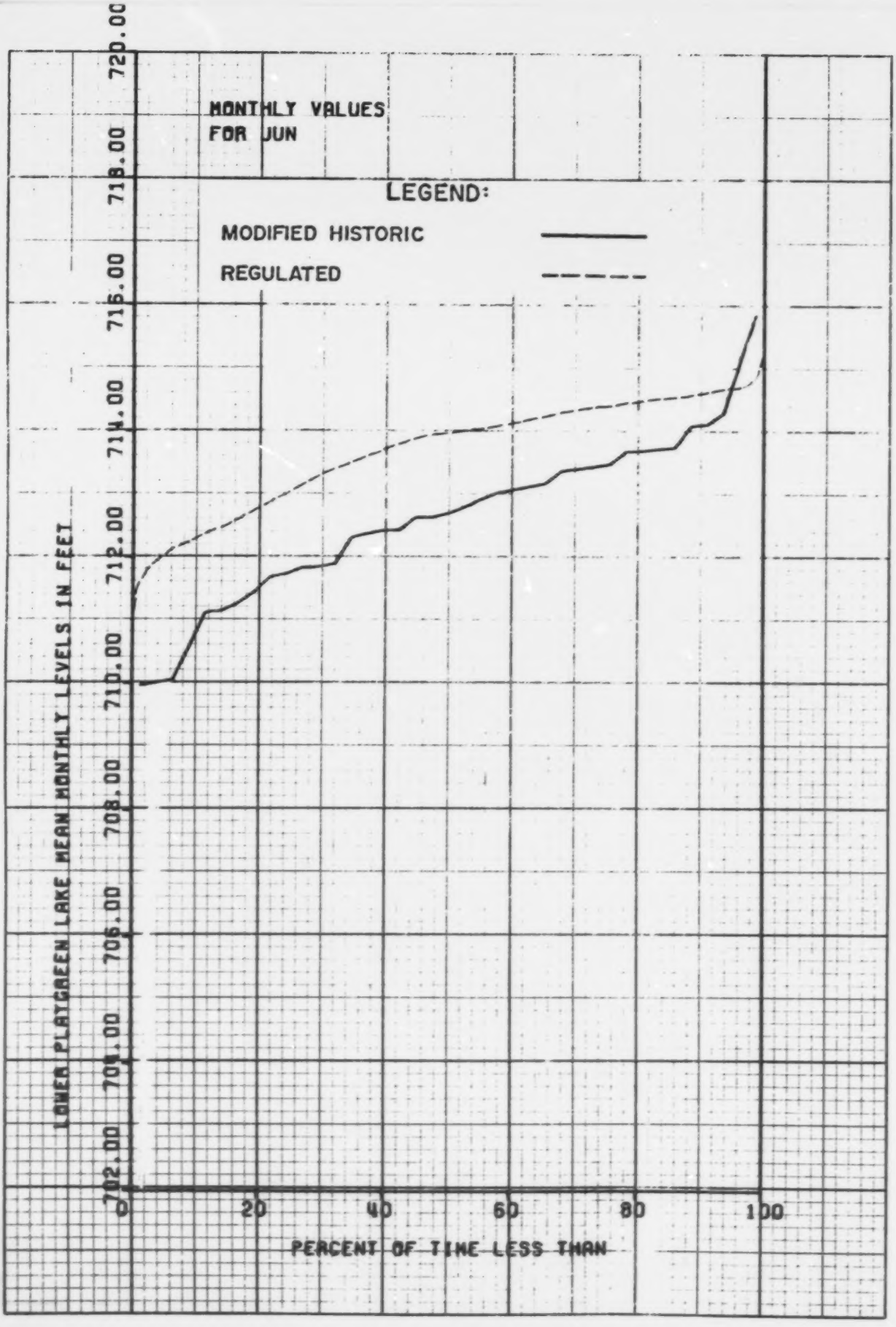

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

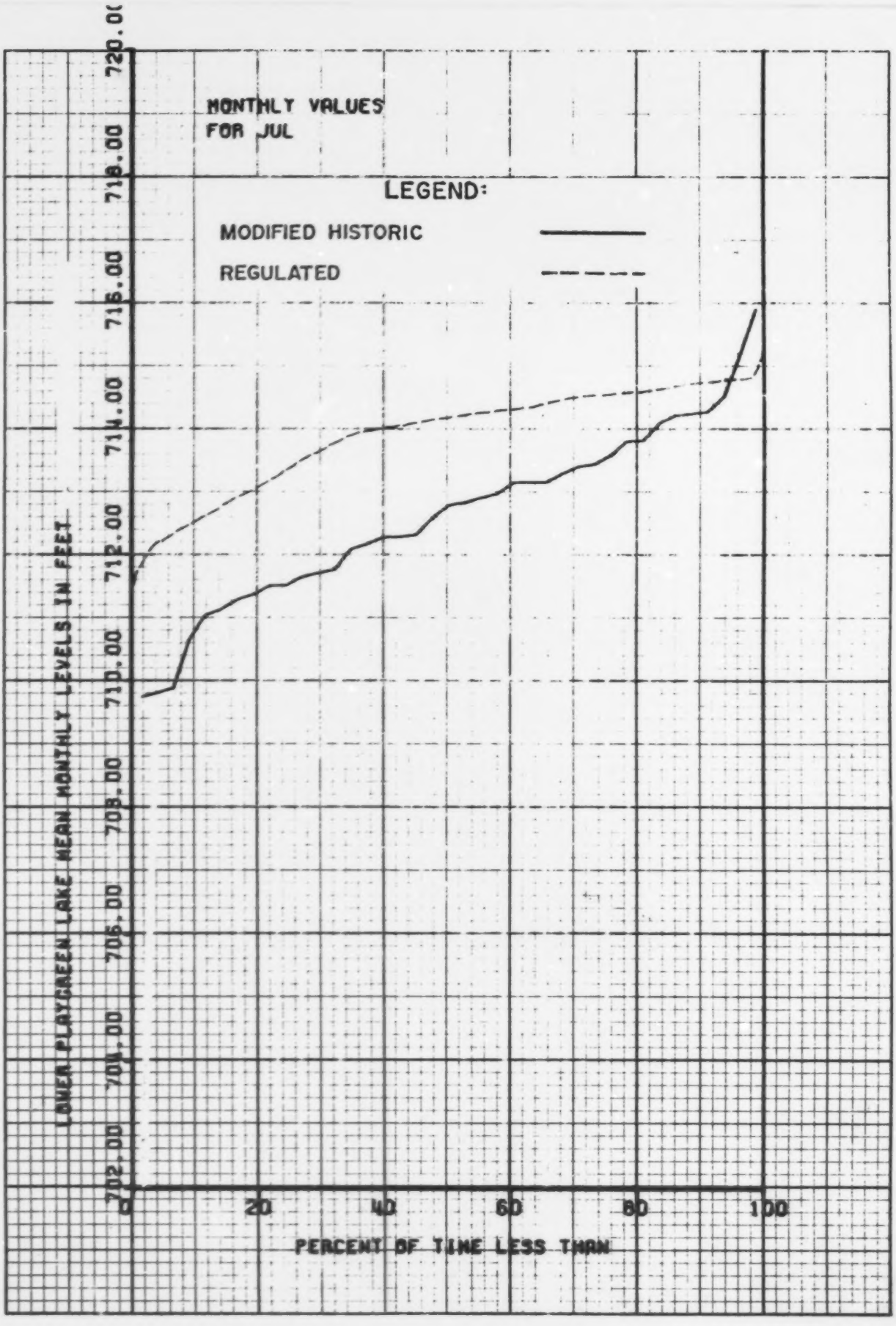

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

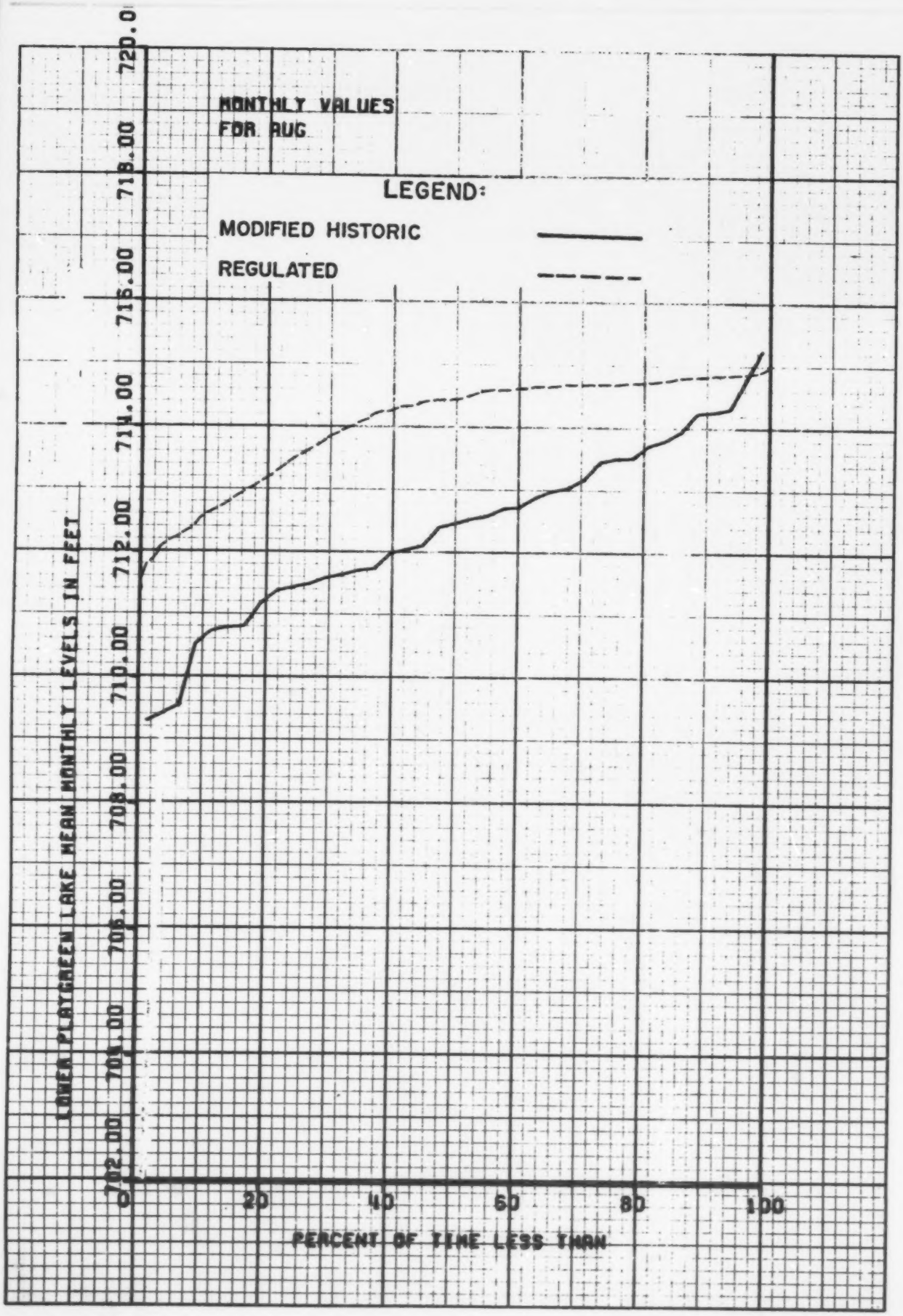

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

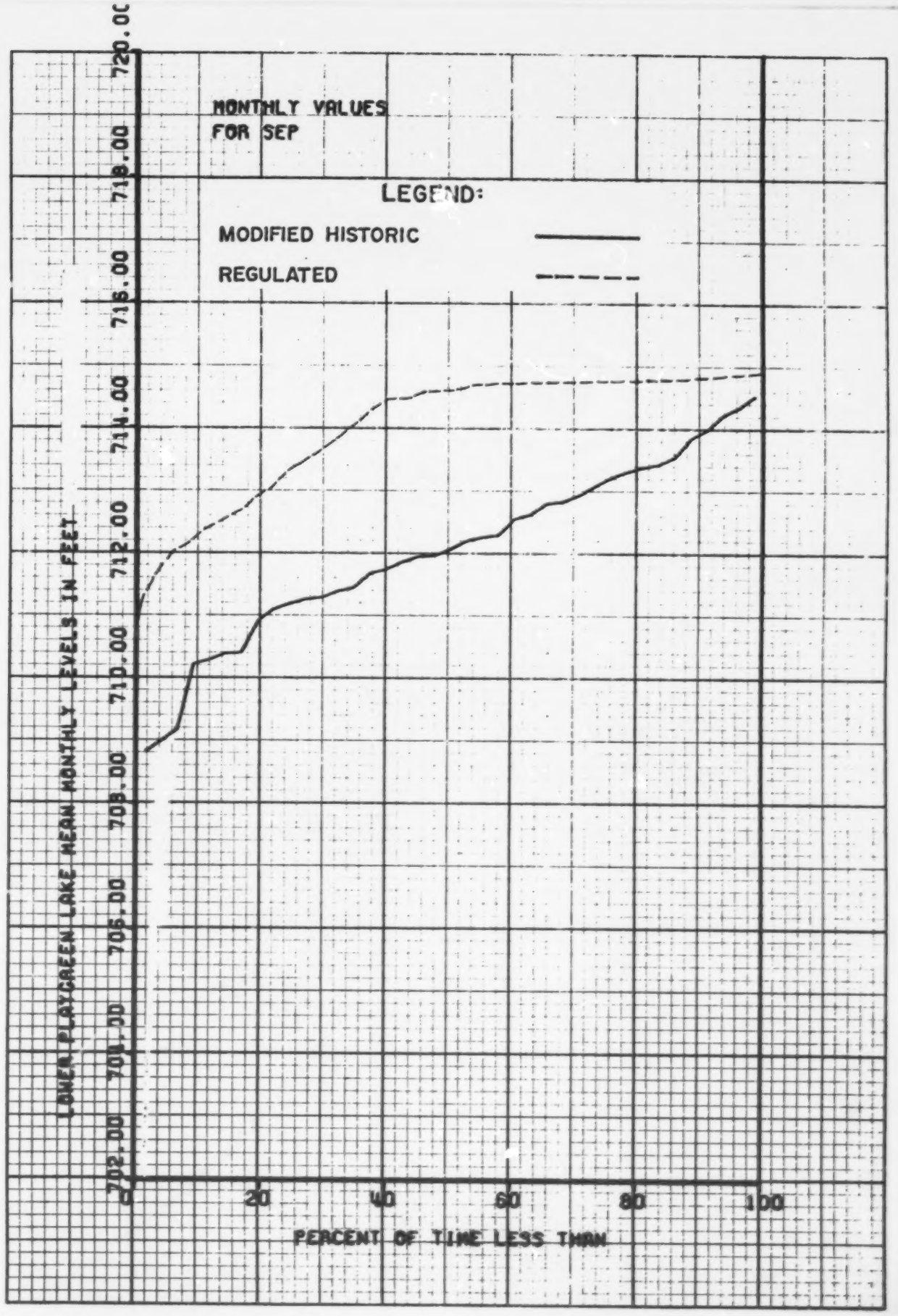

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLATGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

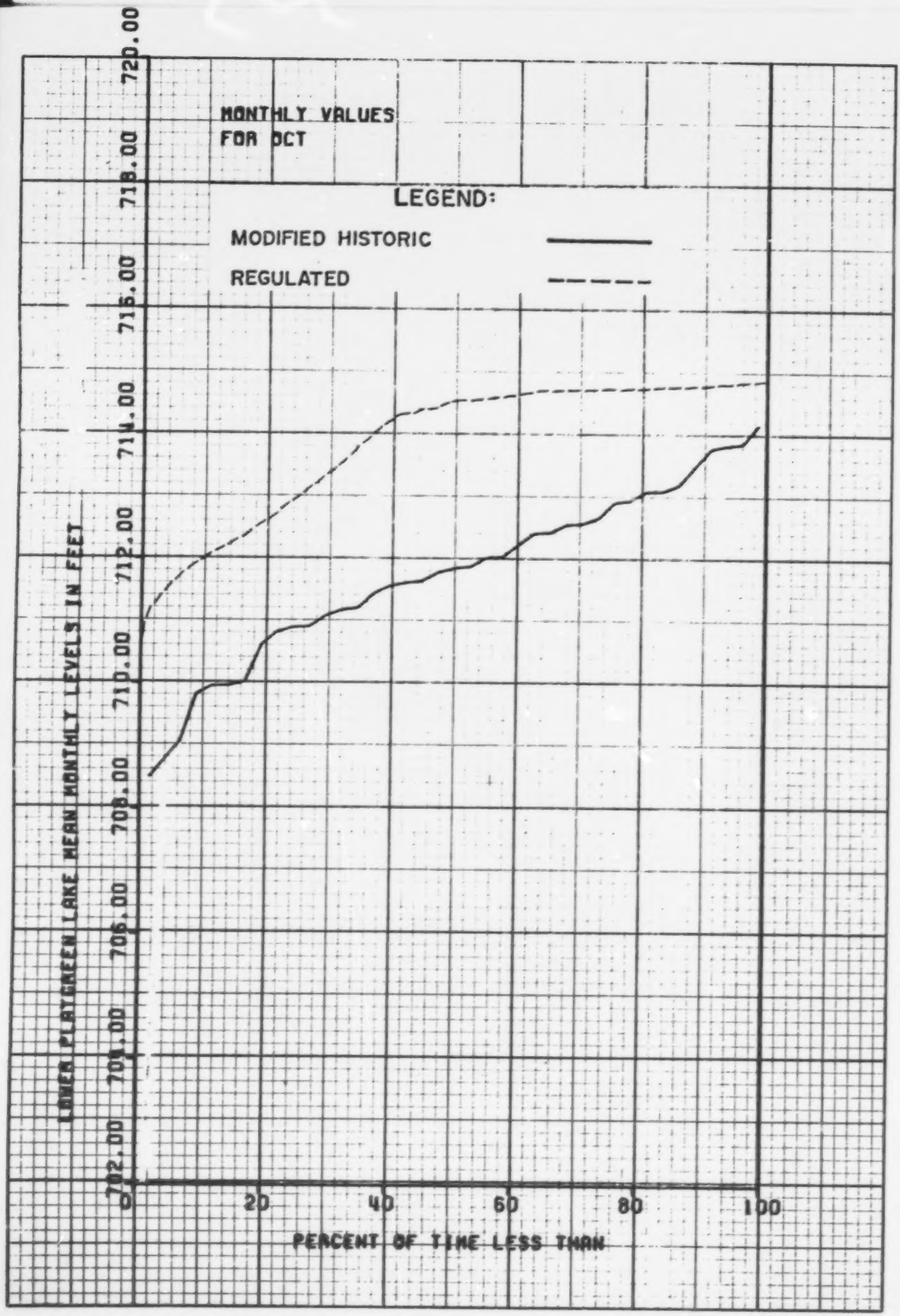

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.0
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

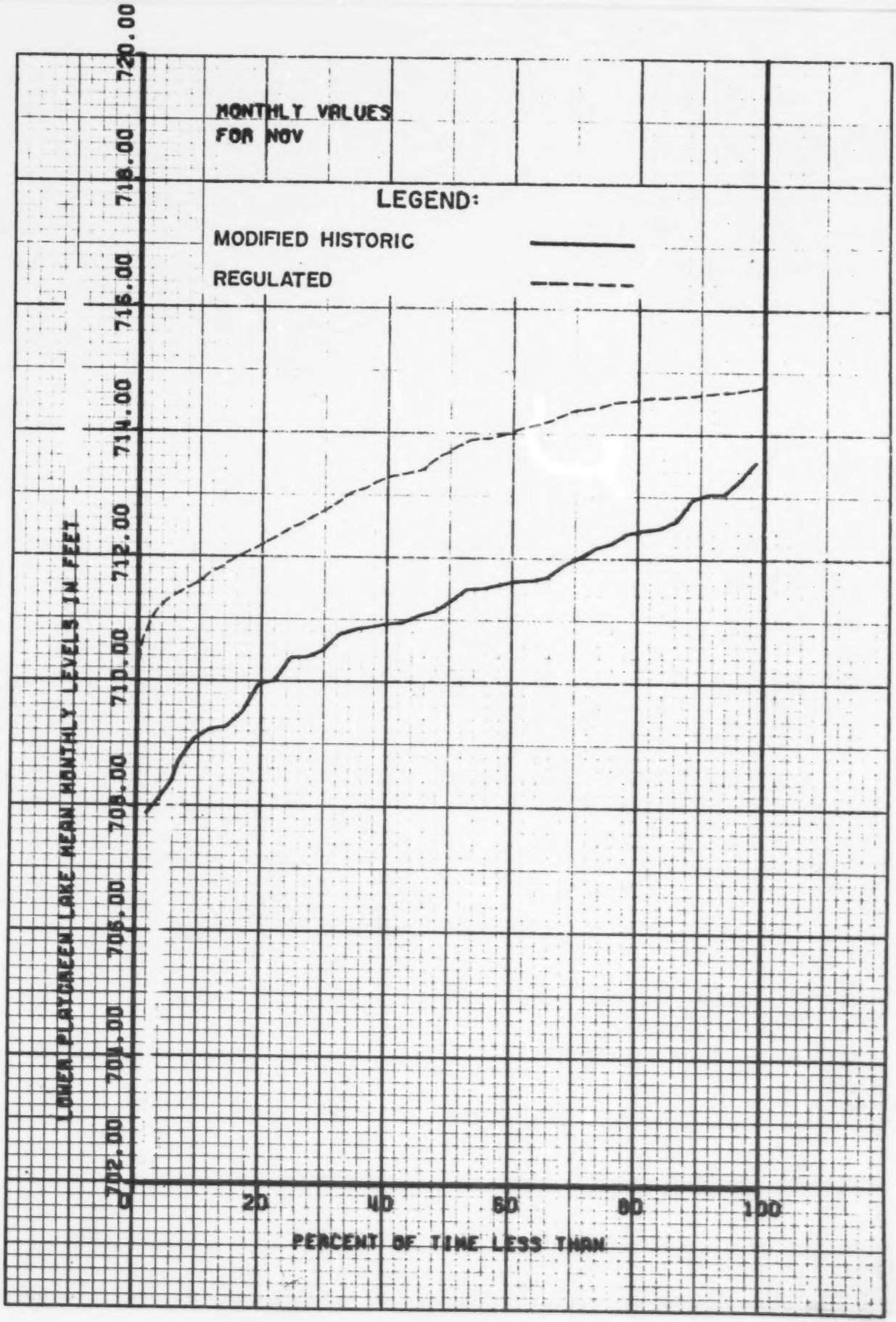

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLATTE GREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

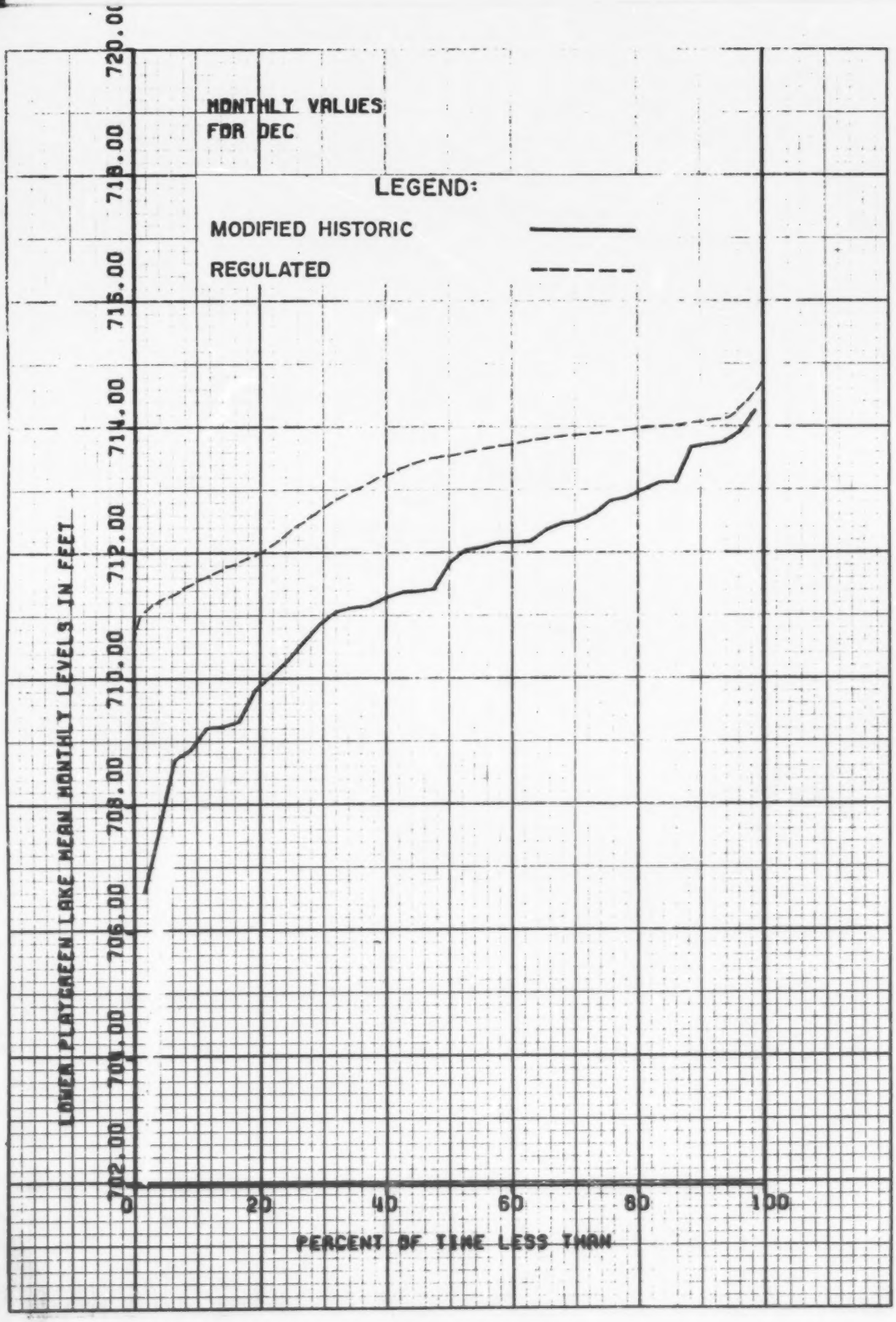

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLATTEGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLATTSMOUTH LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
LOWER PLATTSBURGH LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

Playgreen Lake (North End)
Levels

UPPER PLAYGREEN LAKE-MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	3	95	45	55	97	3	24	0	61	29	92	3	39	61	11	89	3	97	0	100	3	97	50	34
1 - 2	0	3	0	0	0	0	74	0	8	0	5	0	0	0	0	0	0	0	0	0	0	0	0	13
2 - 4	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

													ANNUAL
MINIMUM	703.60	703.81	704.20	706.17	708.31	708.81	708.59	708.15	707.63	707.28	706.59	704.42	703.60
AVERAGE	709.31	709.31	709.48	710.70	711.01	711.50	711.49	711.25	710.92	710.62	710.02	709.79	710.45
MAXIMUM	712.37	712.29	712.37	713.45	713.80	714.74	714.78	714.18	713.44	713.08	712.43	712.76	714.78

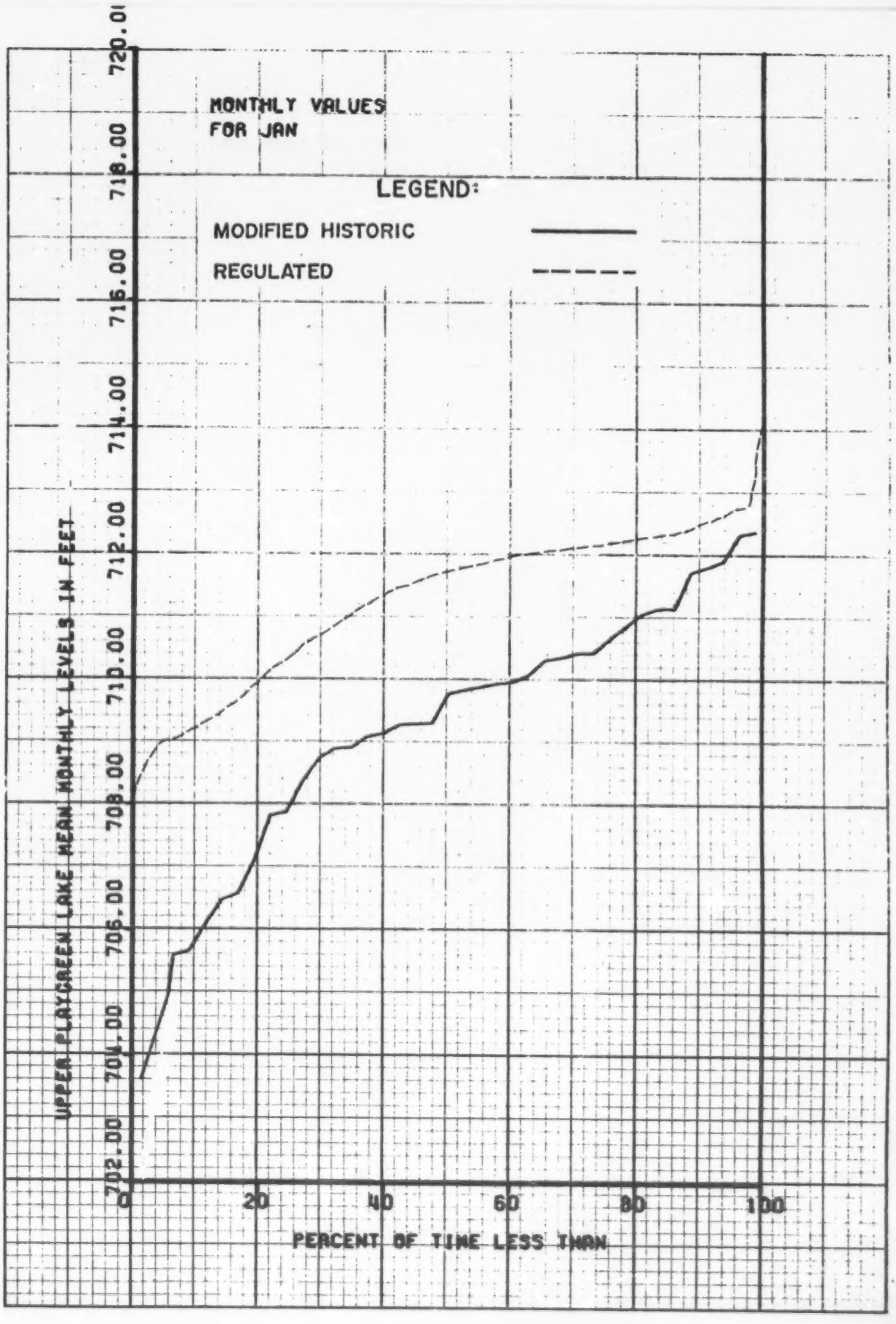
UPPER PLAYGREEN LAKE - REGULATED CONDITIONS

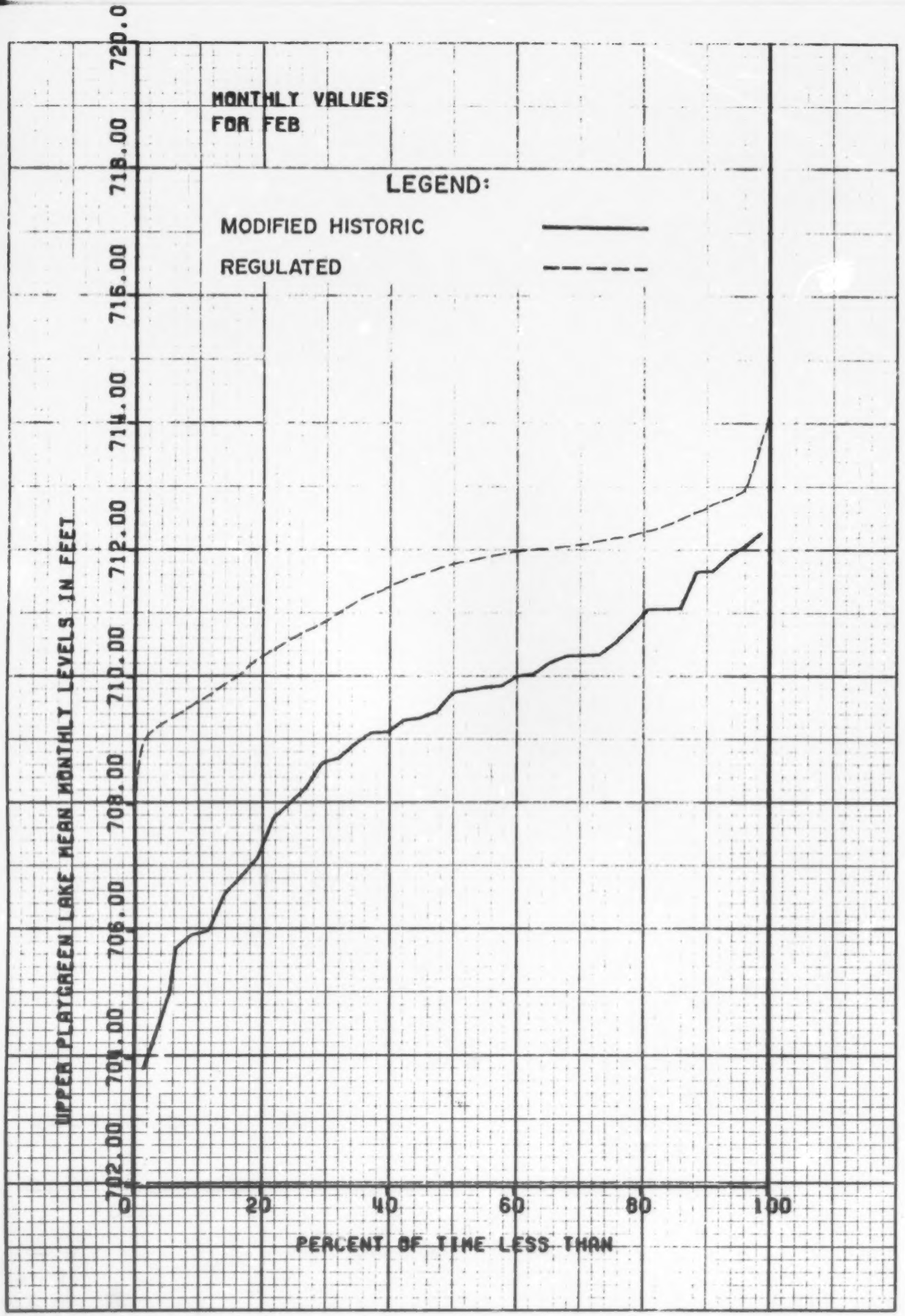
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

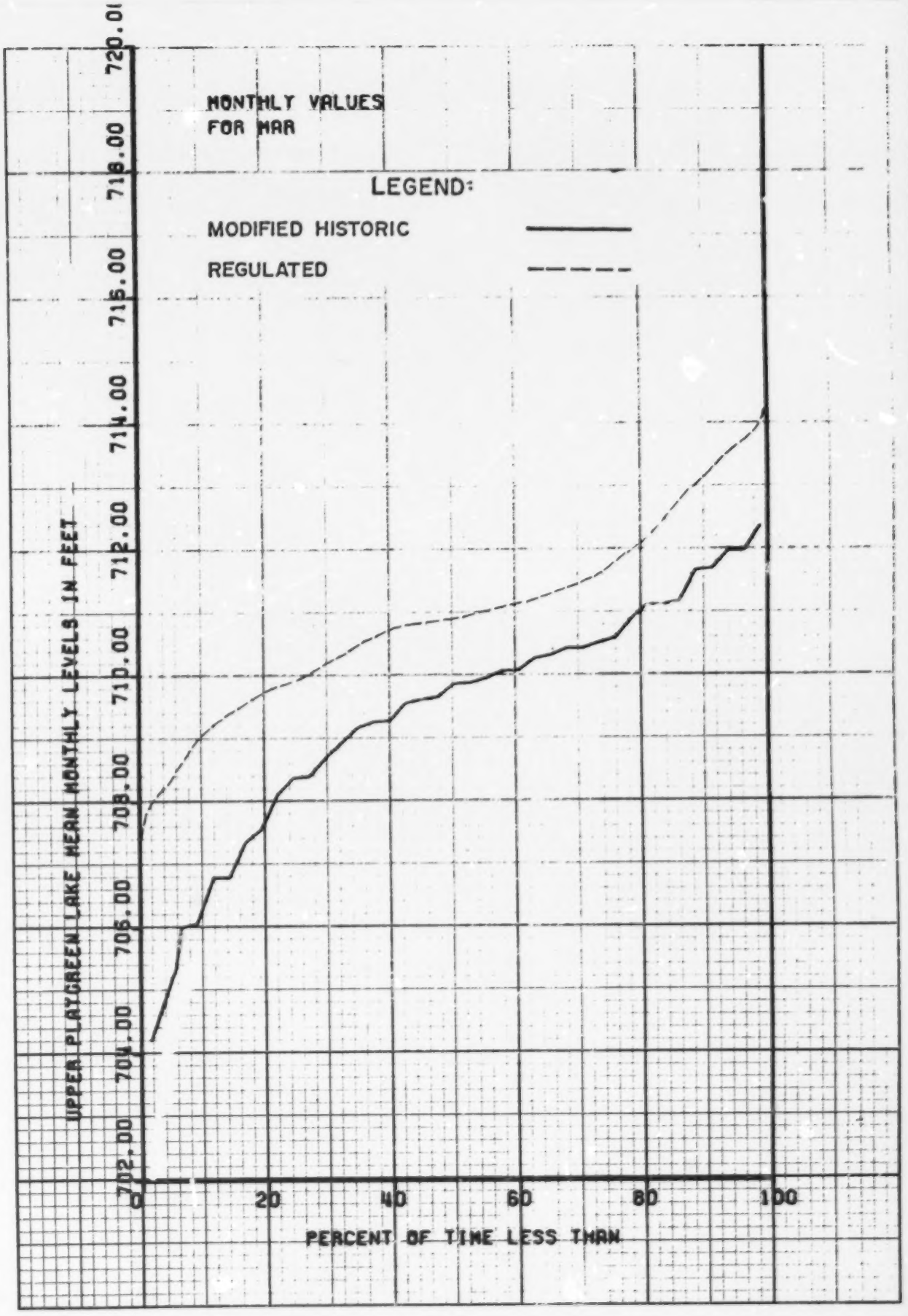
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	0	69	68	28	21	13	30	25	31	6	56	31	66	22	59	26	41	53	35	61	10	47	10	29
1 - 2	0	28	3	0	10	53	23	3	37	0	6	6	6	4	15	0	3	2	1	2	0	18	19	40
2 - 4	0	3	1	0	2	1	18	1	24	0	1	0	2	0	0	0	0	1	0	1	0	25	2	0
4 - 6	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

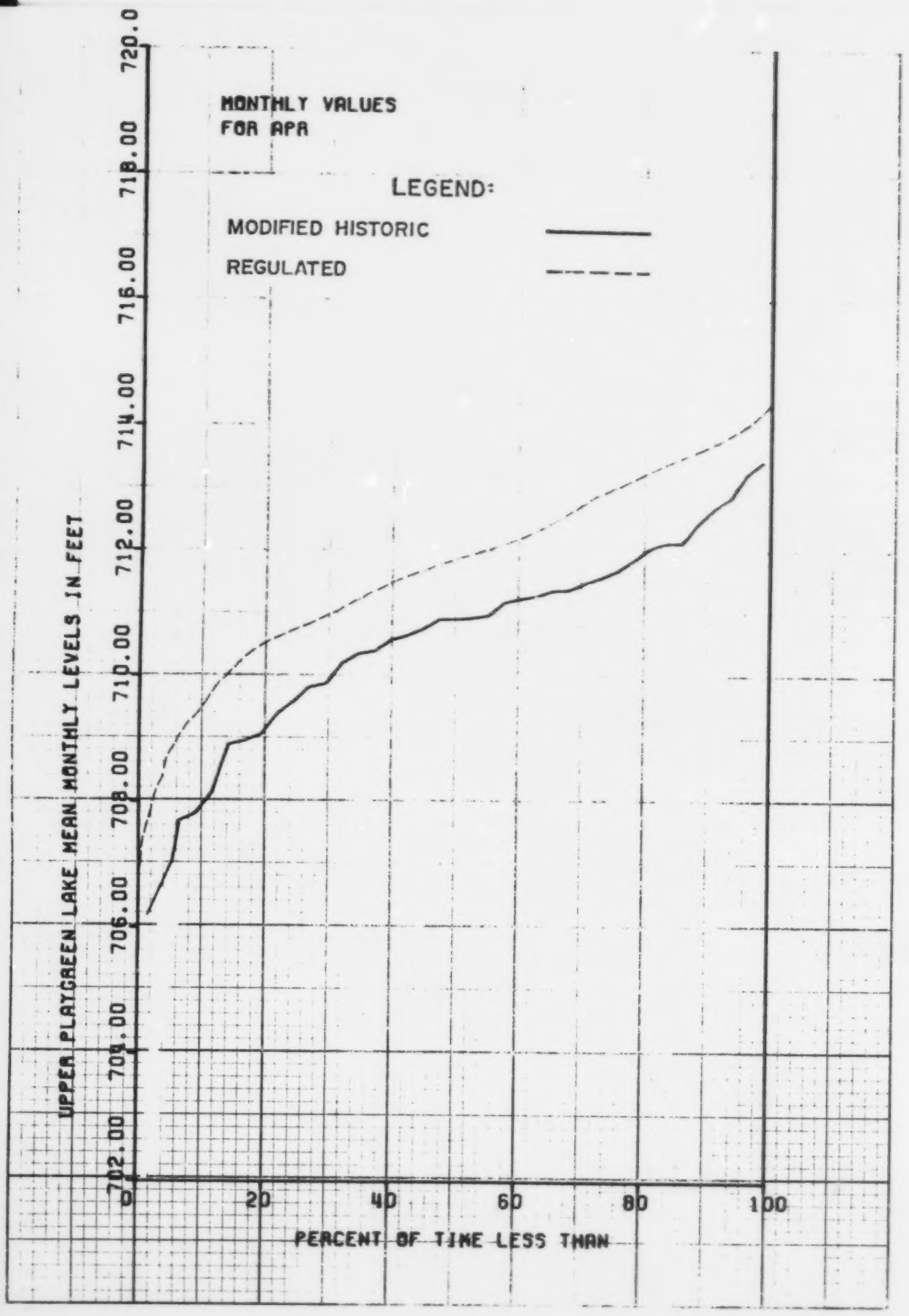
MEAN MONTHLY LEVELS IN FEET

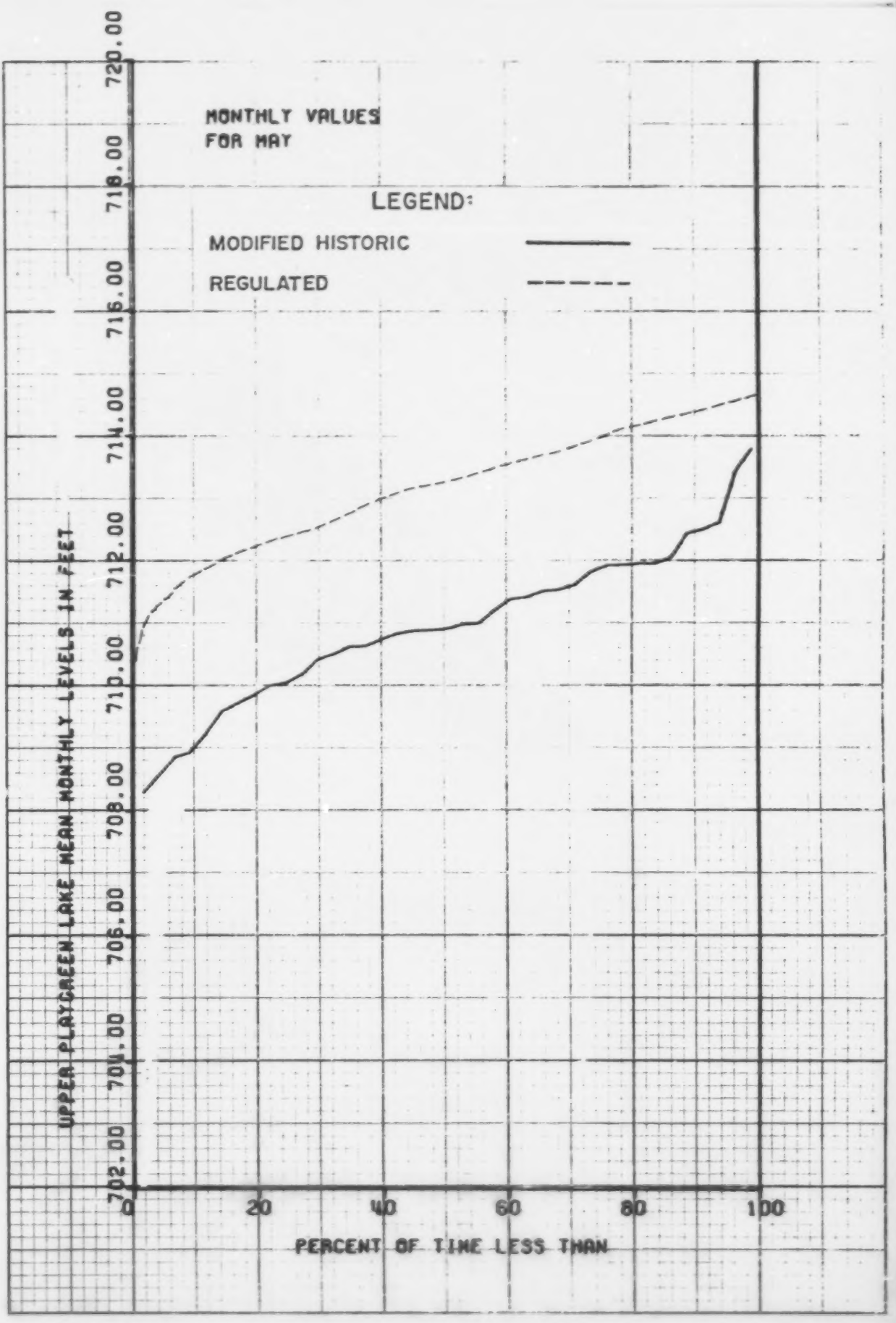
													ANNUAL
MINIMUM	708.09	708.22	707.46	707.26	710.48	709.90	710.45	710.59	709.54	709.37	707.25	709.40	707.25
AVERAGE	711.26	711.43	710.94	711.73	713.16	713.26	713.50	713.82	713.80	713.65	712.48	712.19	712.60
MAXIMUM	714.18	714.27	714.34	714.38	714.73	714.81	714.81	714.95	714.95	714.92	714.76	714.50	714.95

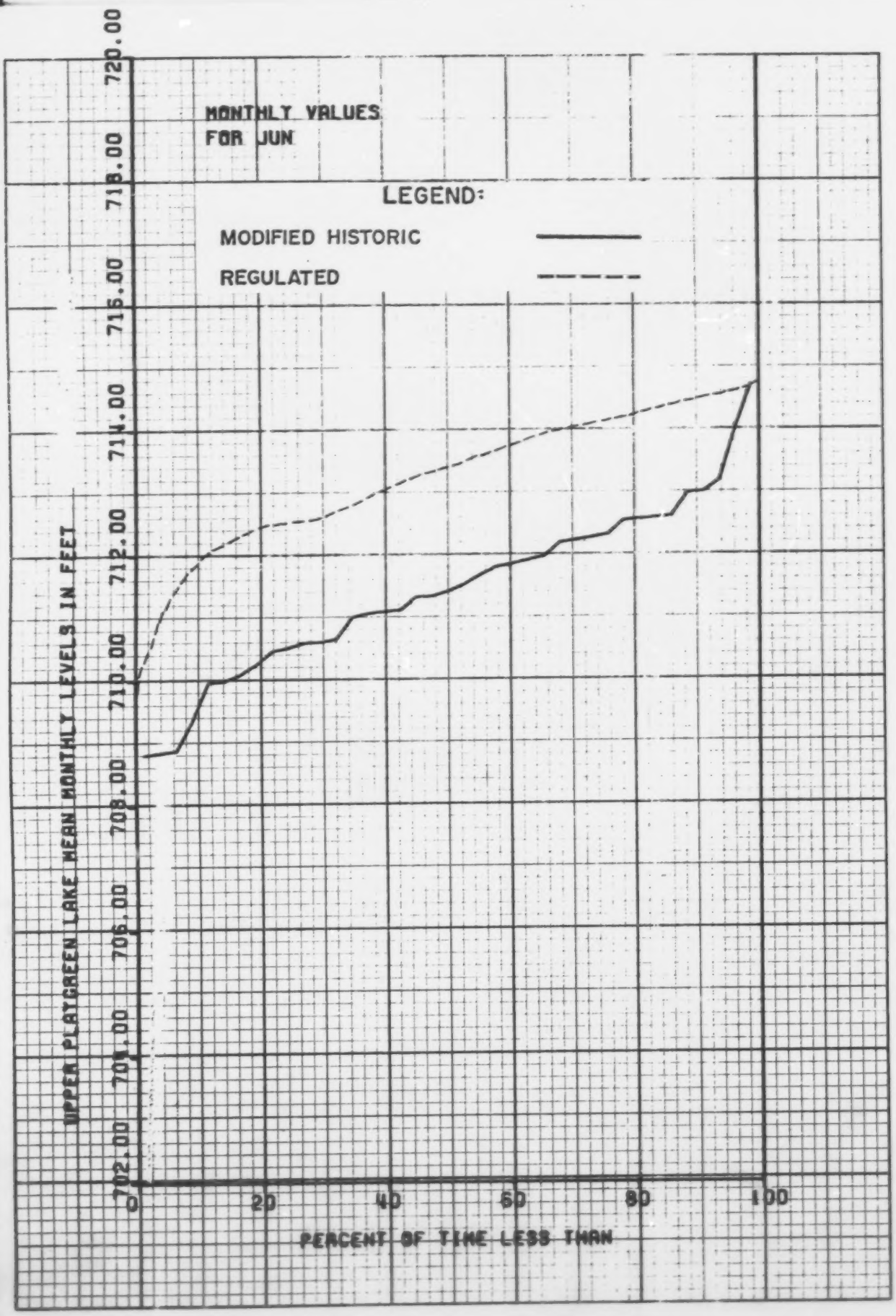

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.01
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

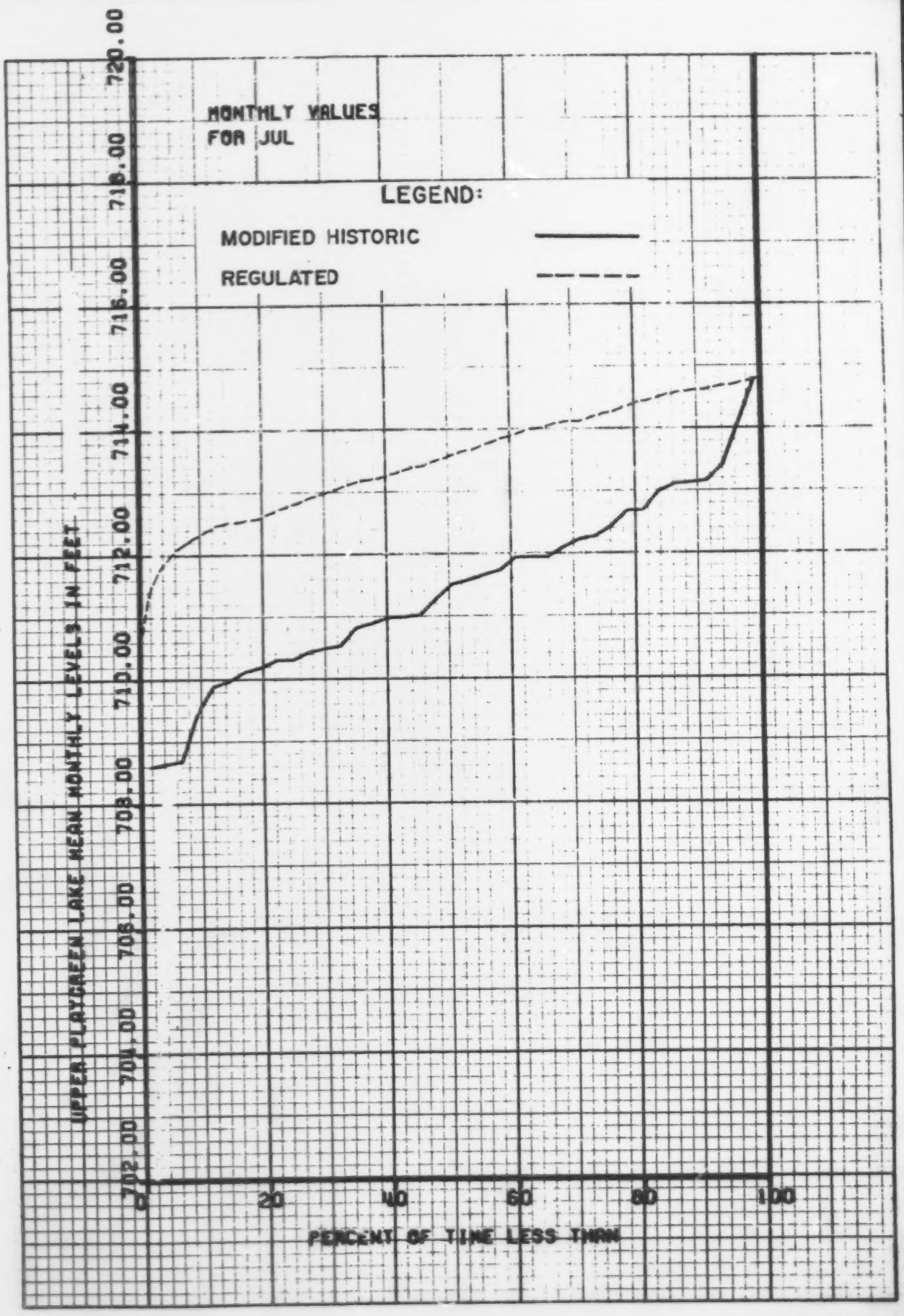

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.0
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

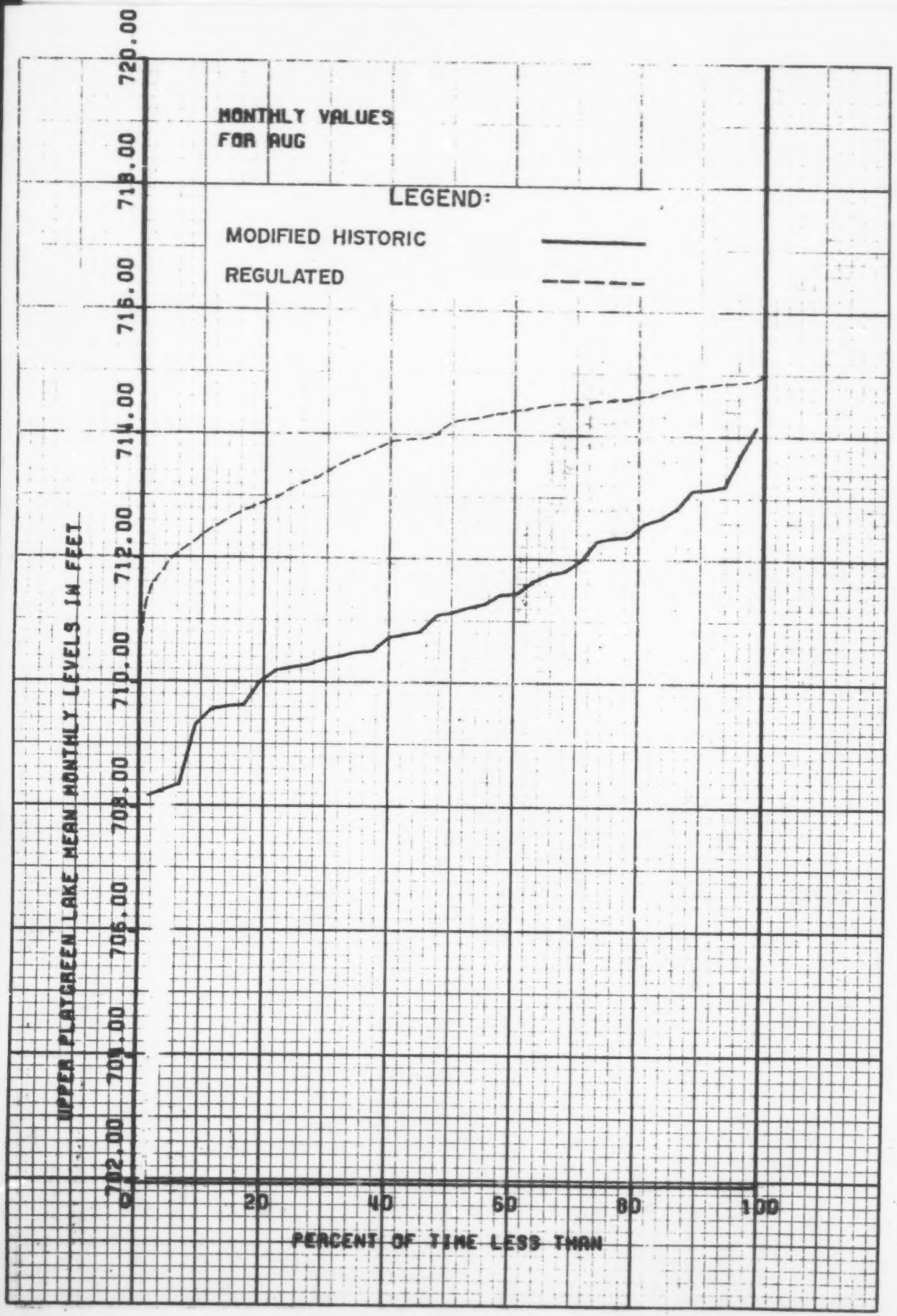

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.01
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

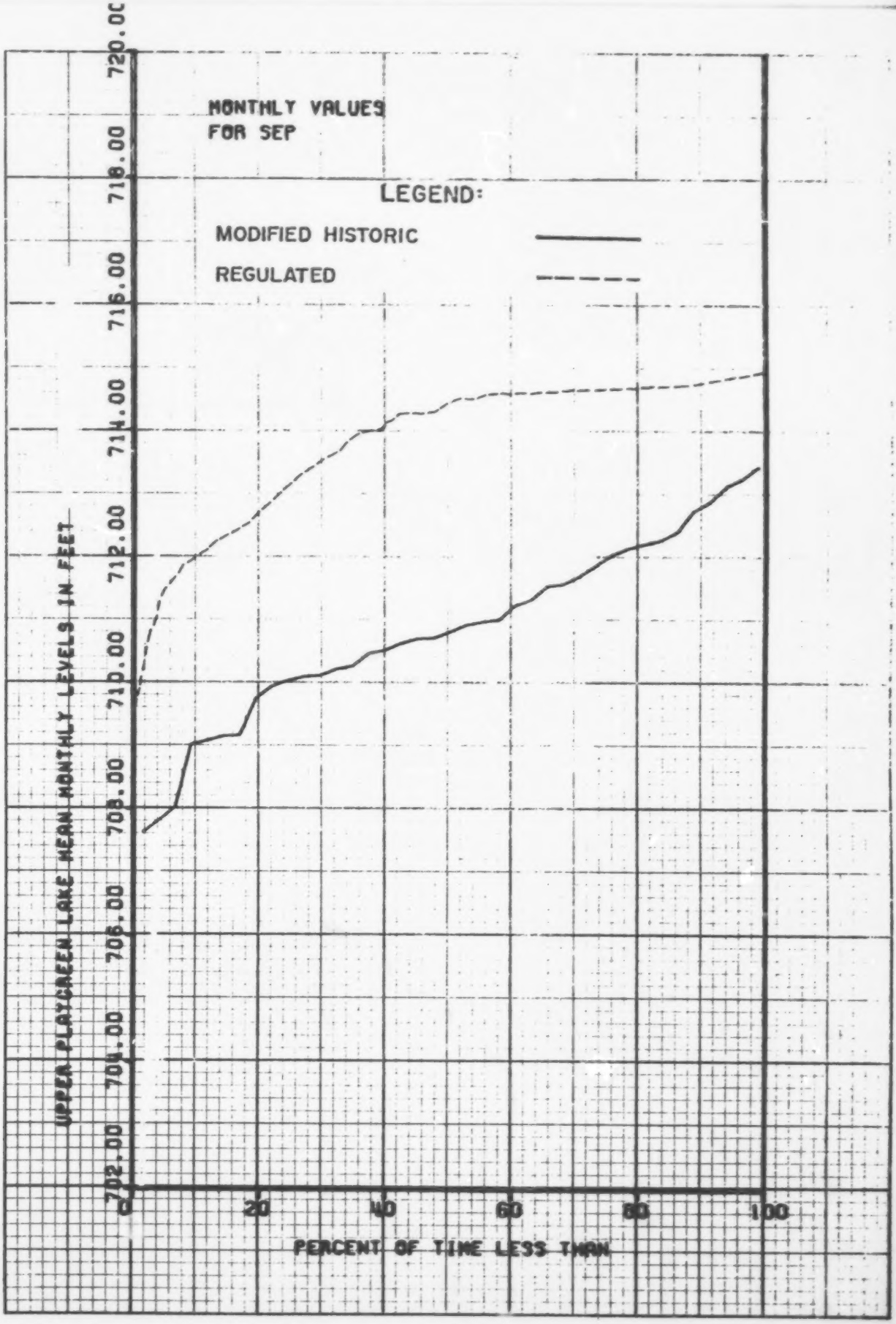

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLATTEEN LAKE MEAN MONTHLY LEVELS IN FEET
720.0
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

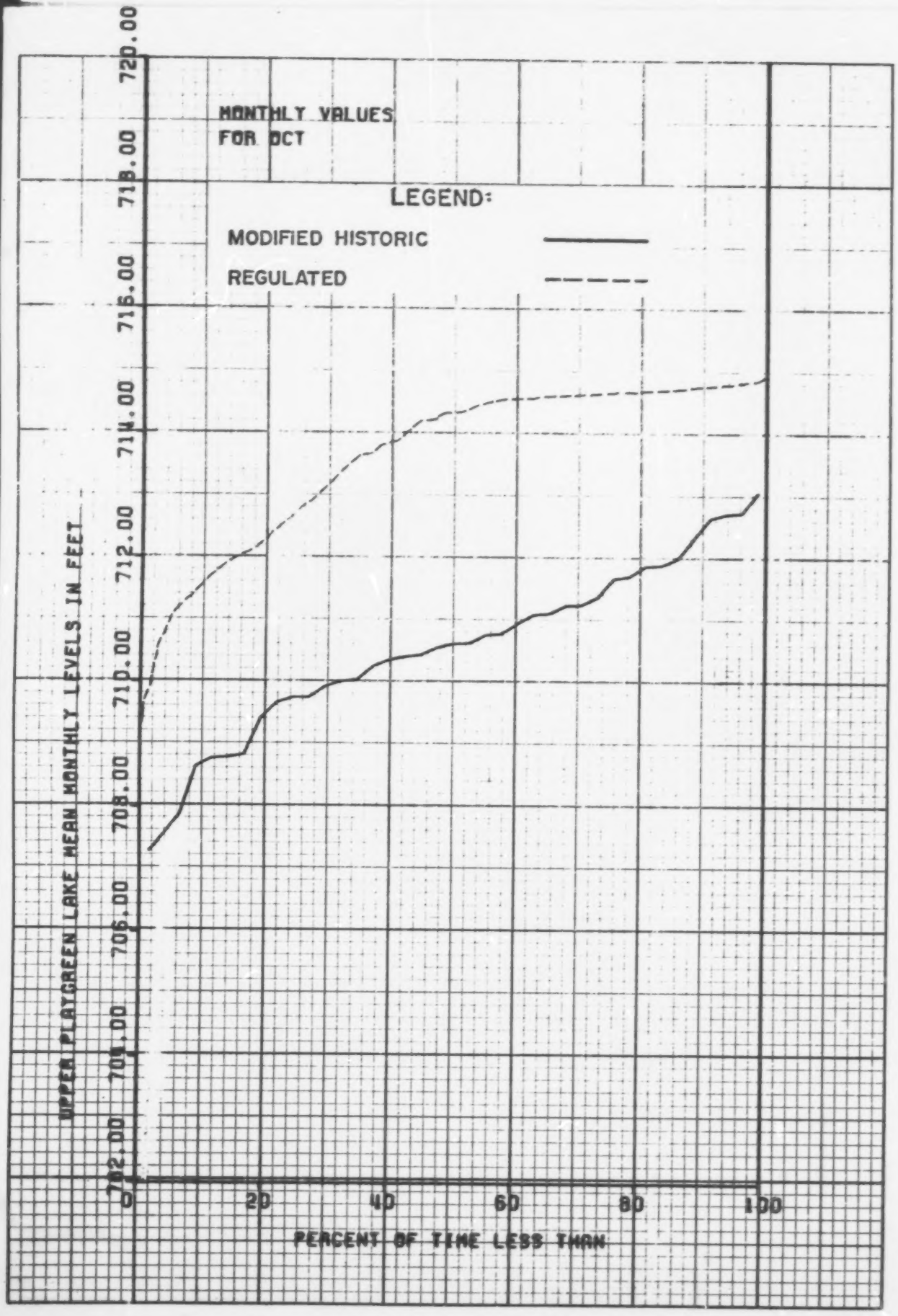

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

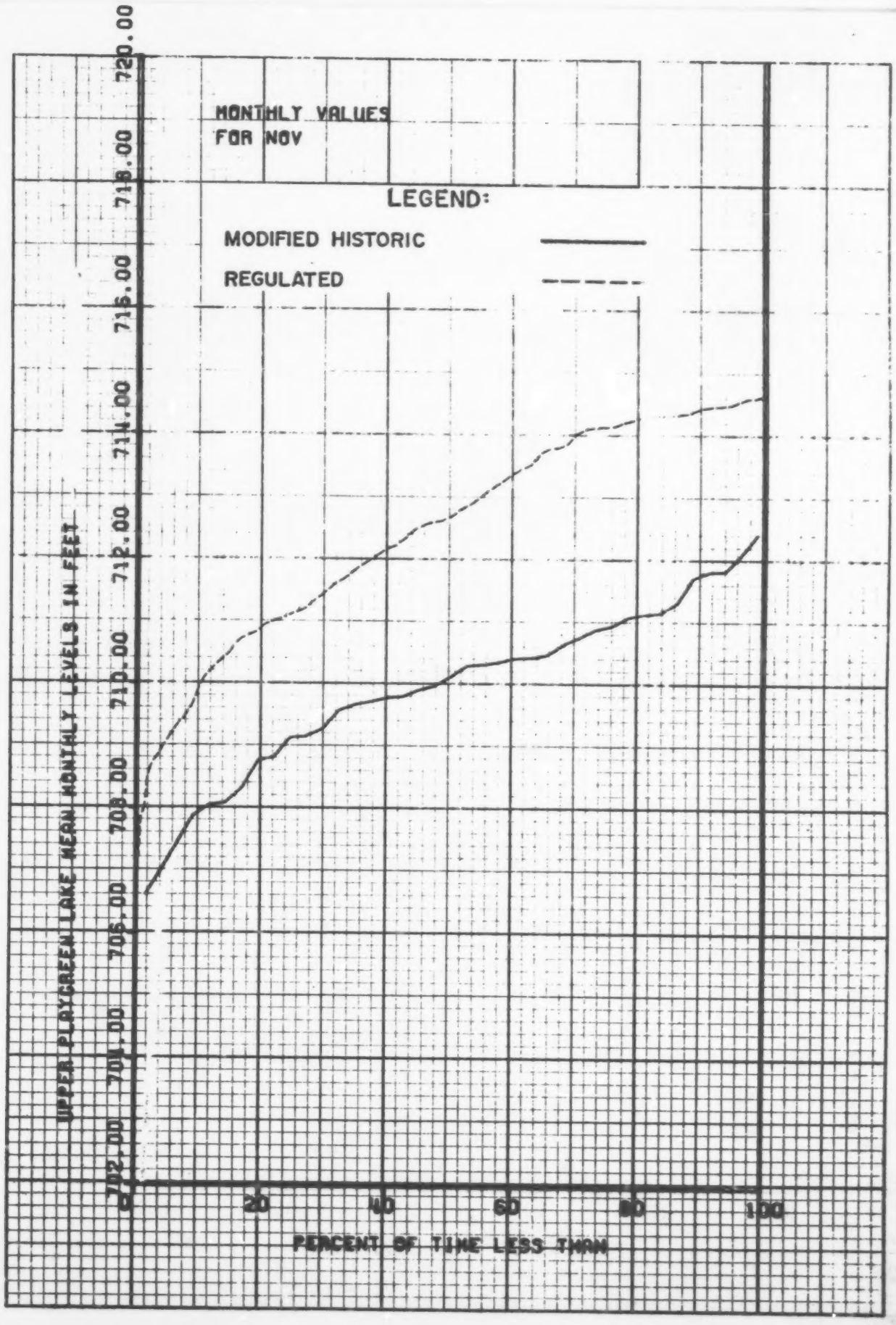

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLATTE GREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

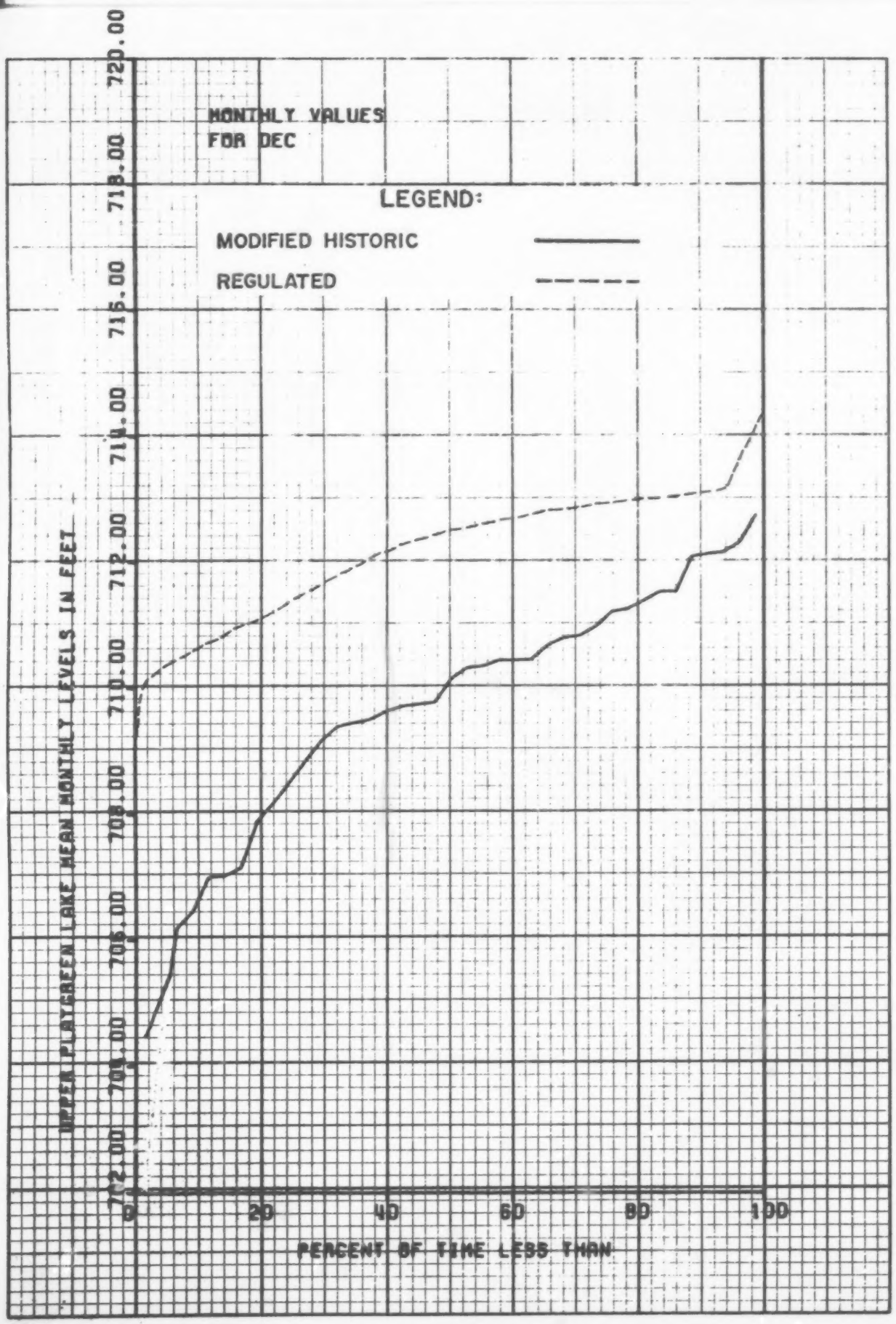

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLATTE GREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLATTSBURGH LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLATTE GREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
UPPER PLAYGREEN LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

Kiskittogisu Lake Levels

KISKITTOGISU LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	3	95	47	53	95	5	74	0	34	63	97	3	39	61	11	89	3	97	0	100	3	97	76	16
1 - 2	0	3	0	0	0	0	24	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
2 - 4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

MINIMUM	703.60	703.81	704.20	706.17	707.95	708.34	708.17	707.82	707.42	707.15	706.59	704.42	ANNUAL 703.60
AVERAGE	708.91	708.92	709.06	710.00	710.01	710.38	710.37	710.19	709.94	709.72	709.26	709.29	709.67
MAXIMUM	711.18	711.12	711.18	711.99	712.07	712.73	712.75	712.34	711.81	711.56	711.08	711.47	712.75

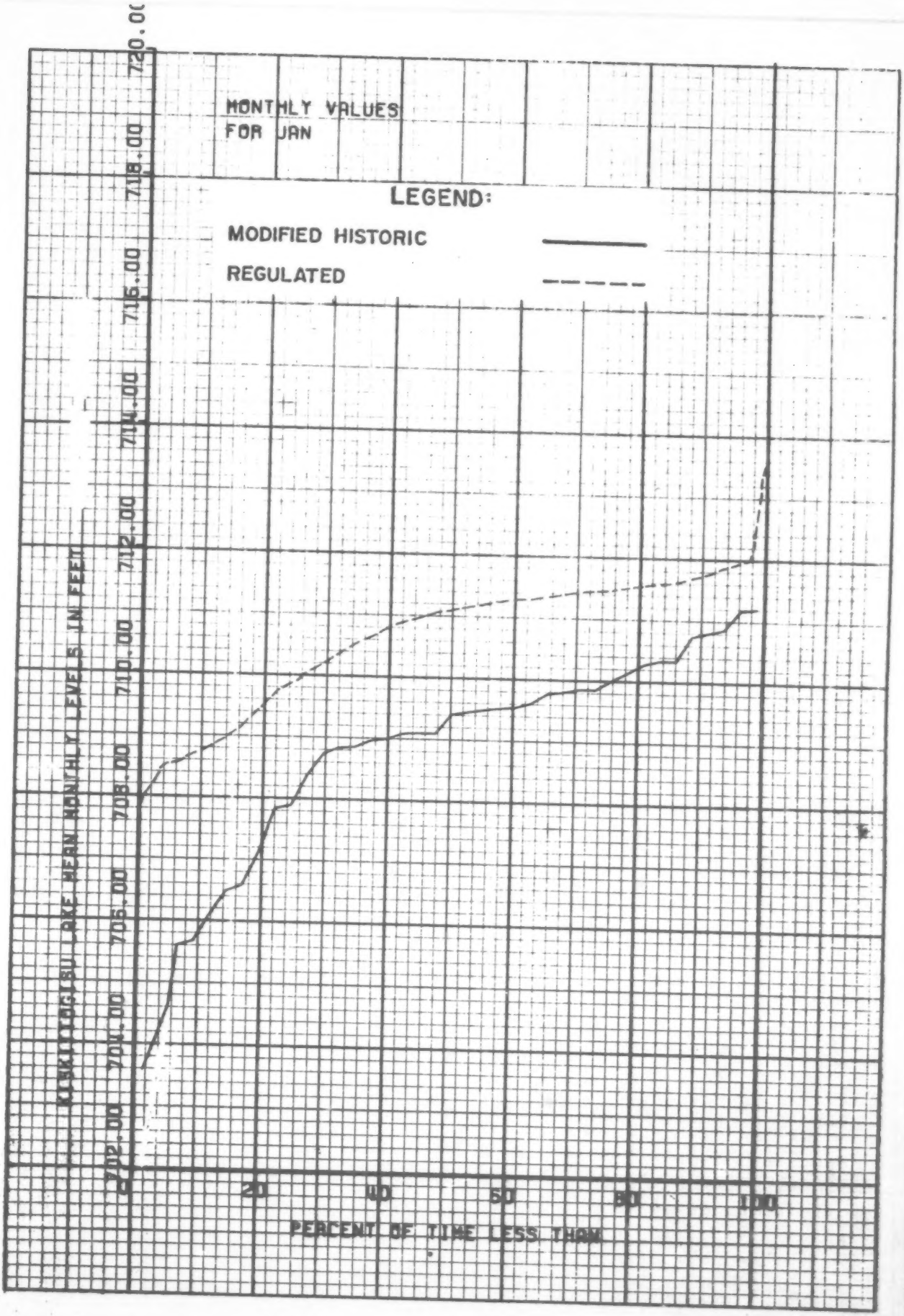
KISKITTOGISU LAKE - REGULATED CONDITIONS

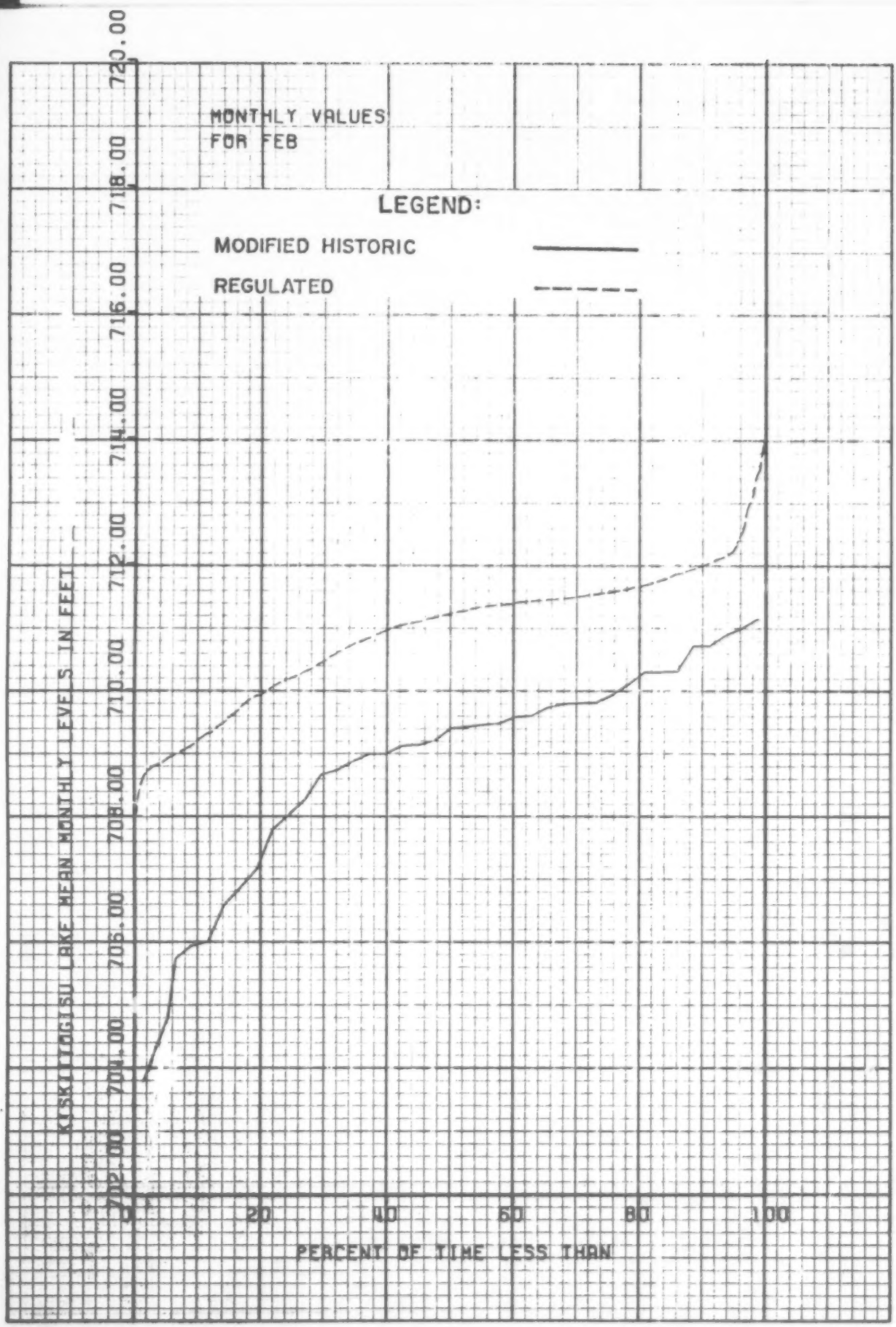
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

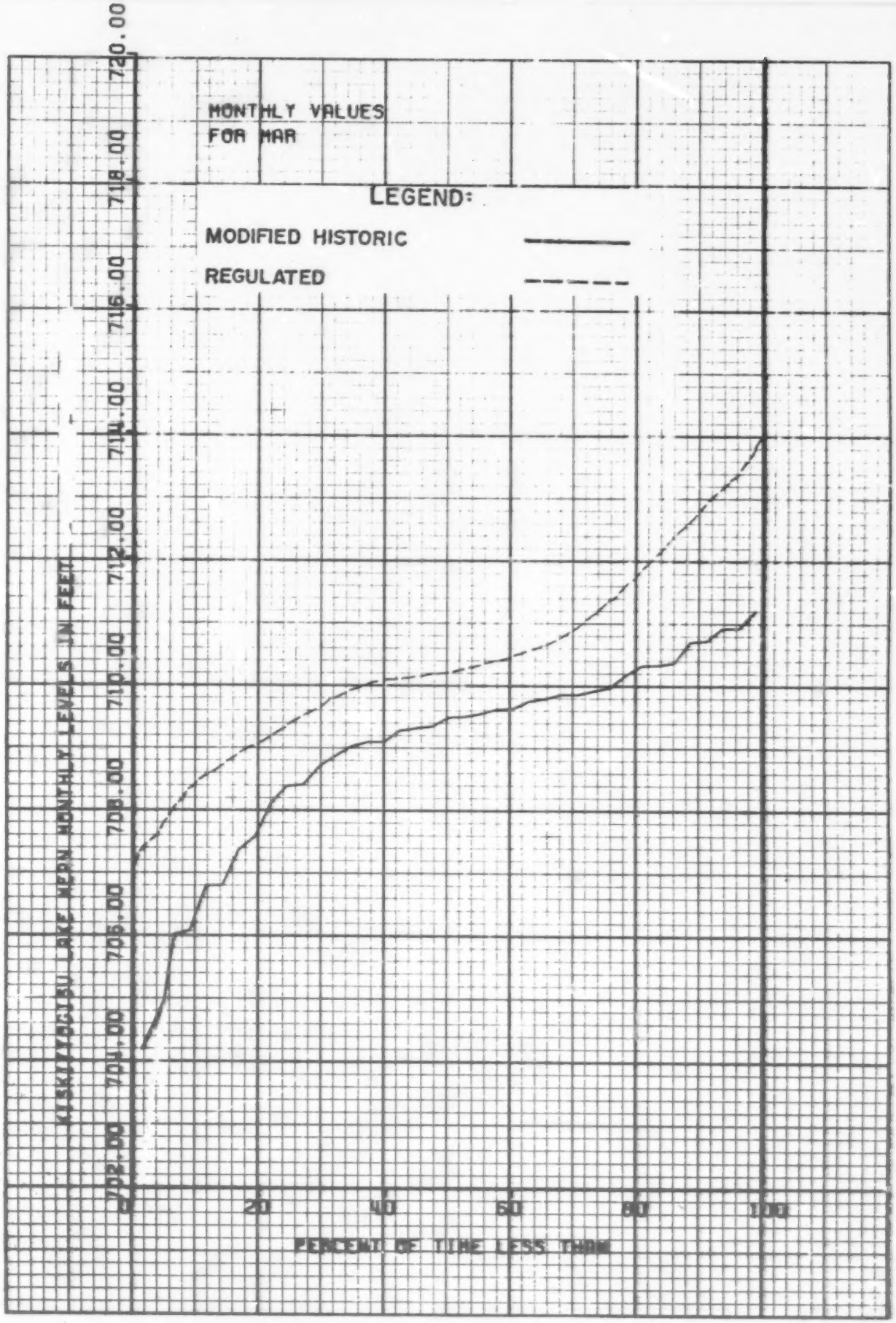
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	0	71	76	19	17	9	25	25	25	6	52	25	59	21	54	25	38	54	34	59	10	41	10	22
1 - 2	0	24	4	0	13	57	21	2	35	3	4	11	8	4	11	1	2	1	1	4	0	18	2	27
2 - 4	0	5	1	0	3	1	24	2	26	0	4	4	5	3	9	0	3	2	0	2	0	13	21	18
4 - 6	0	0	0	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

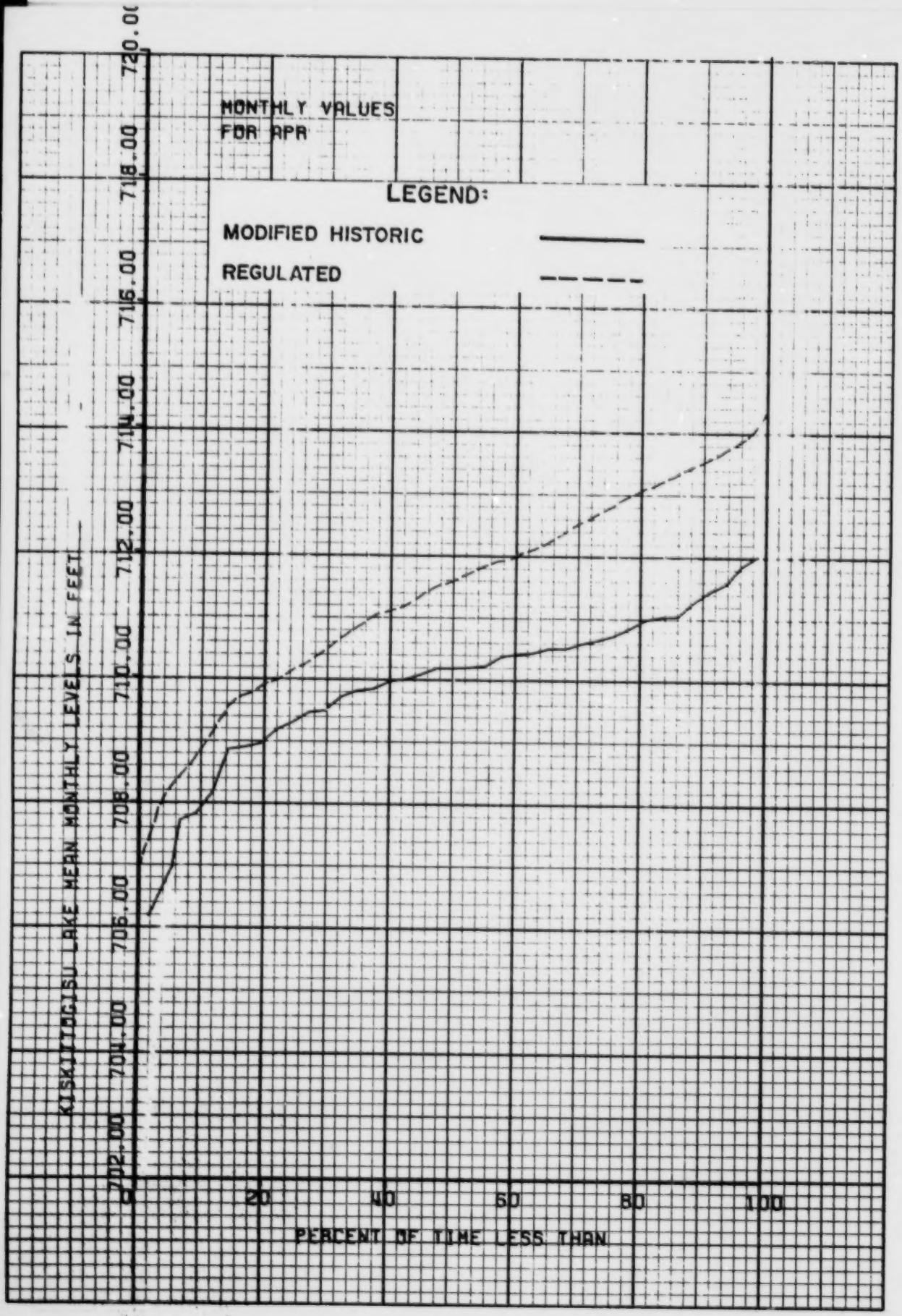
MEAN MONTHLY LEVELS IN FEET

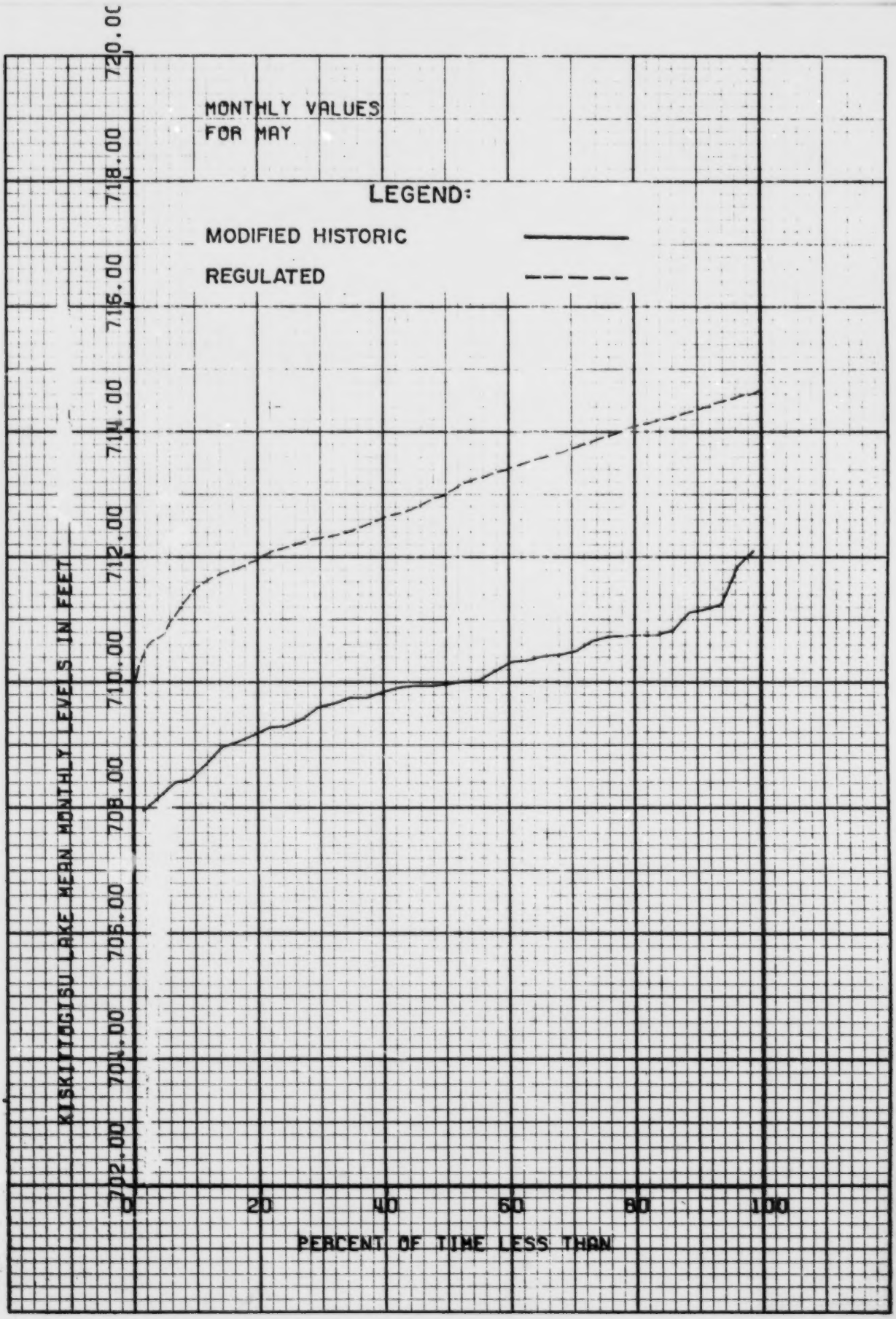
MINIMUM	707.81	707.92	707.08	706.90	710.01	709.15	709.54	710.25	708.89	708.74	706.58	708.68	ANNUAL 706.58
AVERAGE	710.71	710.94	710.44	711.39	712.95	712.93	713.20	713.67	713.70	713.52	711.93	711.57	712.25
MAXIMUM	713.97	714.09	714.17	714.32	714.72	714.81	714.81	714.95	714.95	714.92	714.71	714.36	714.95

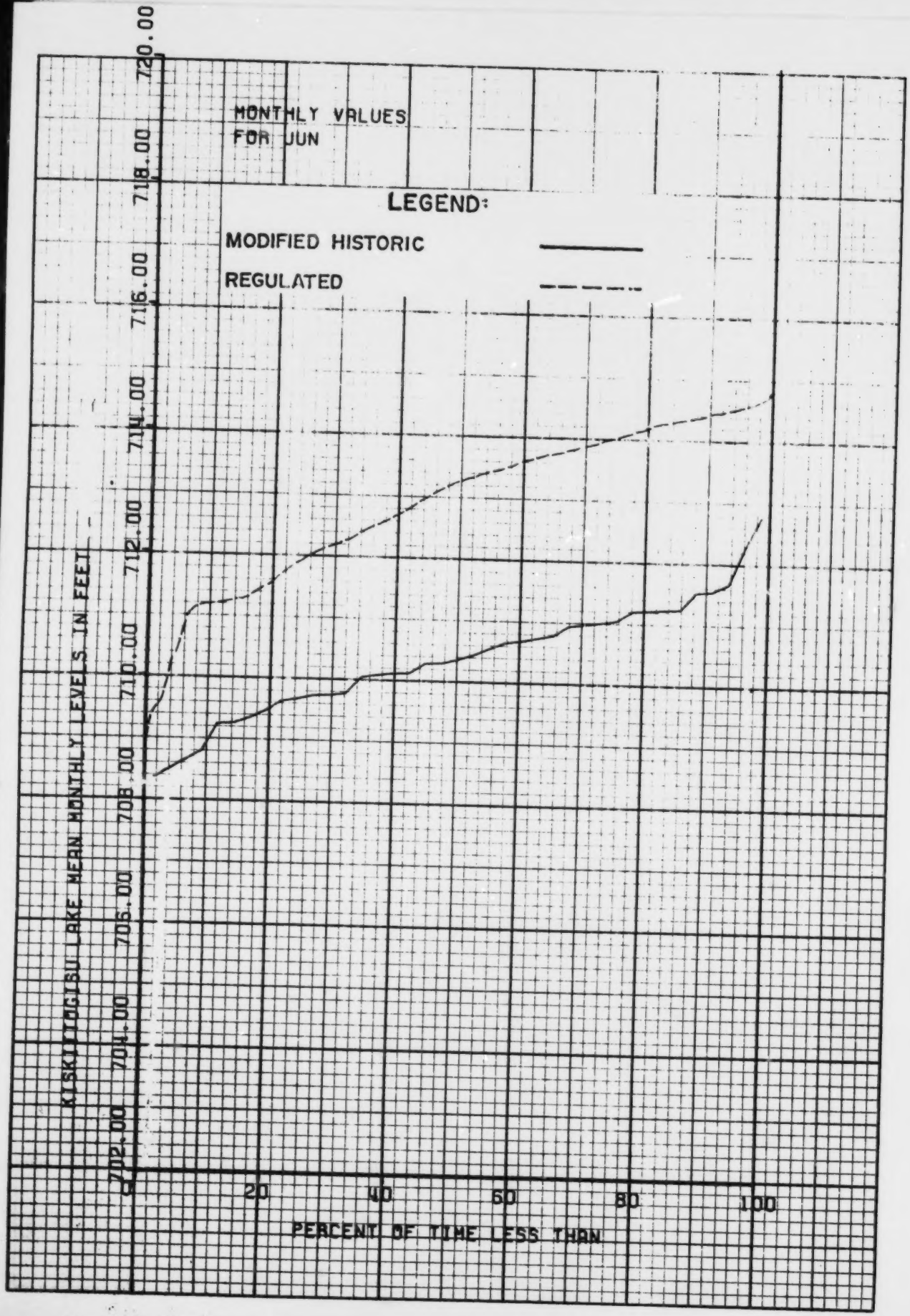

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKI-TOGIAK LAKE MEAN MONTHLY LEVELS IN FEET
702.00
704.00
706.00
708.00
710.00
712.00
714.00
716.00
718.00
720.00
20
40
50
80
100
PERCENT OF TIME LESS THAN

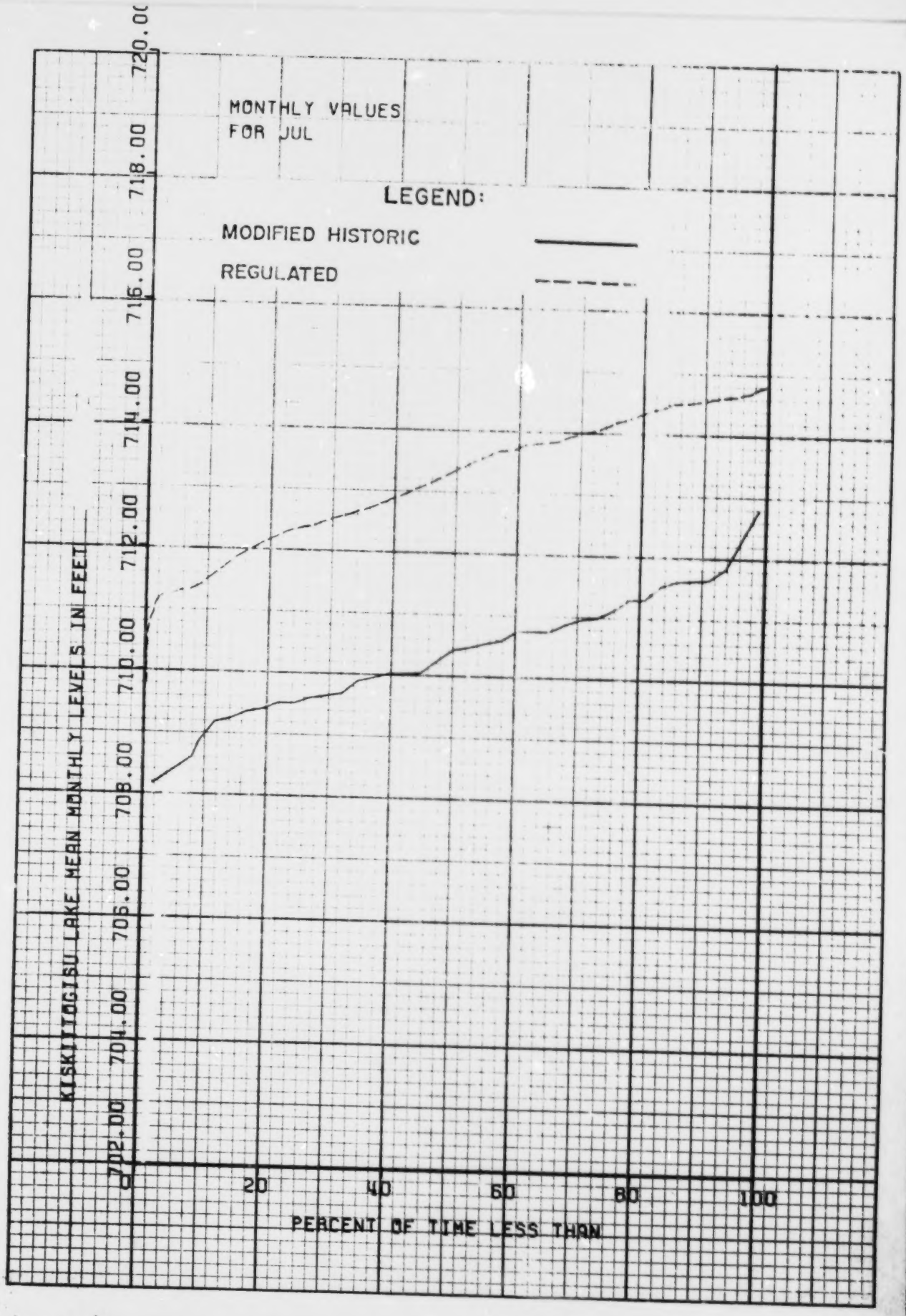

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

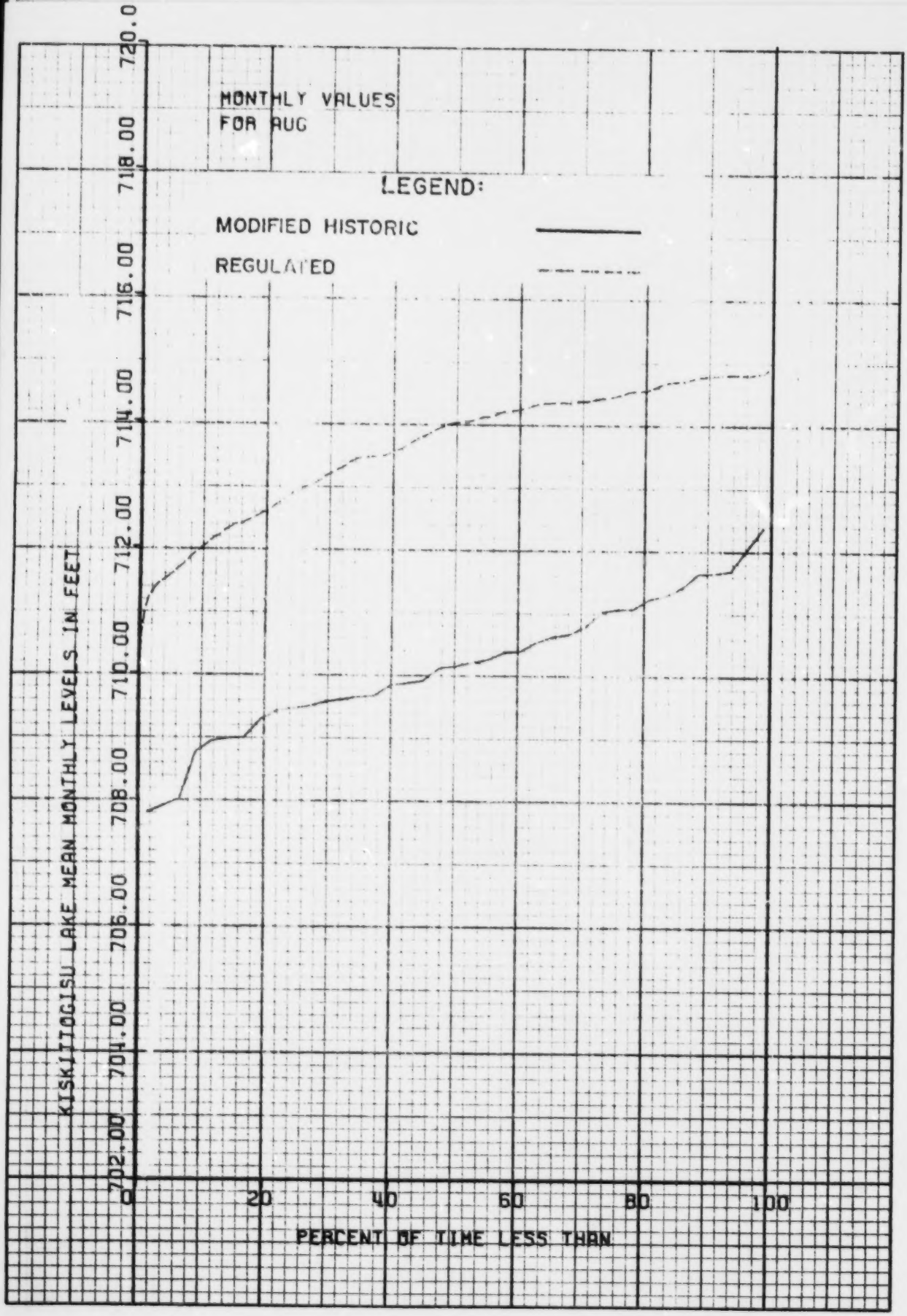

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
KUSKUKOKWIM LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

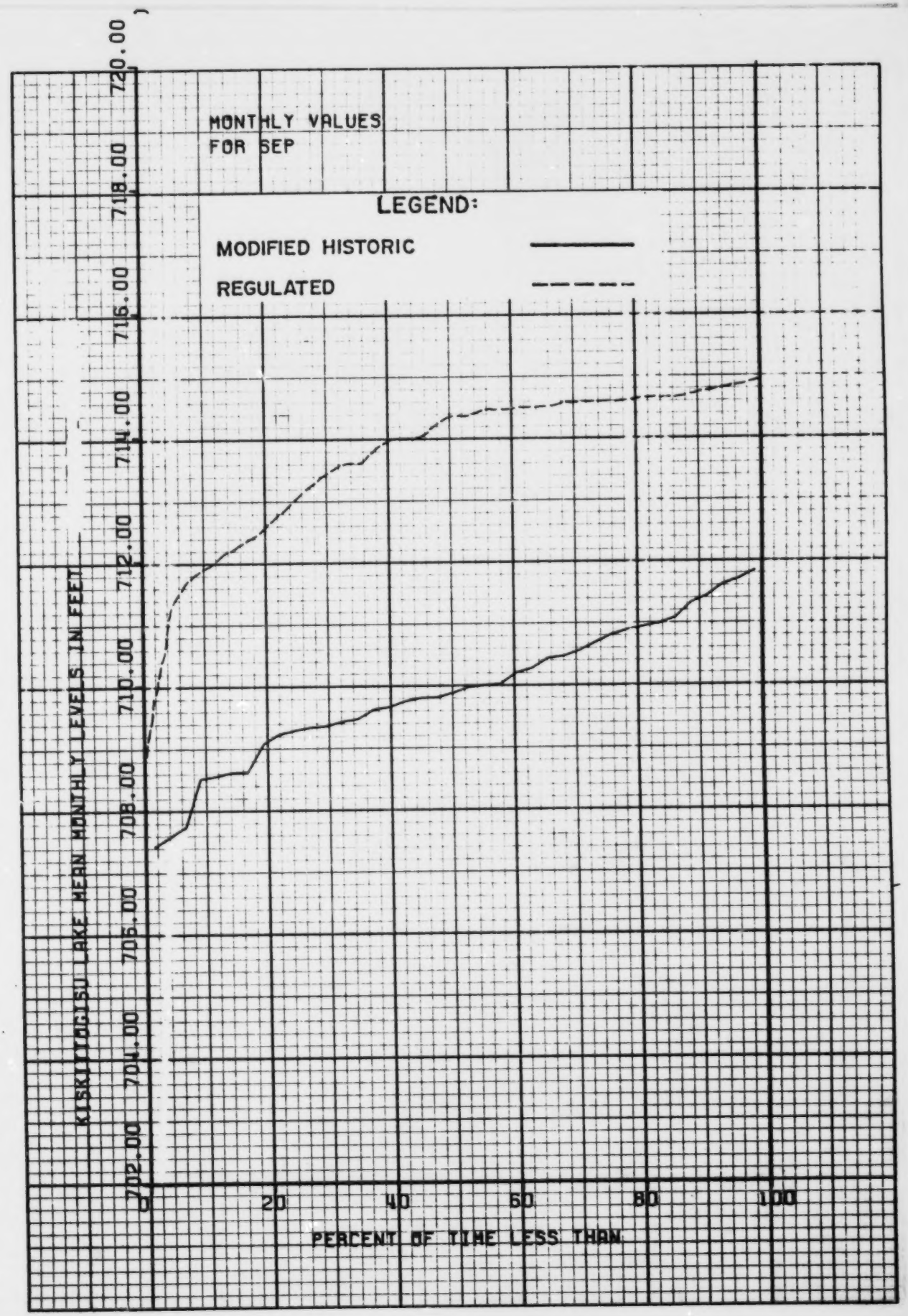

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKILLINGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

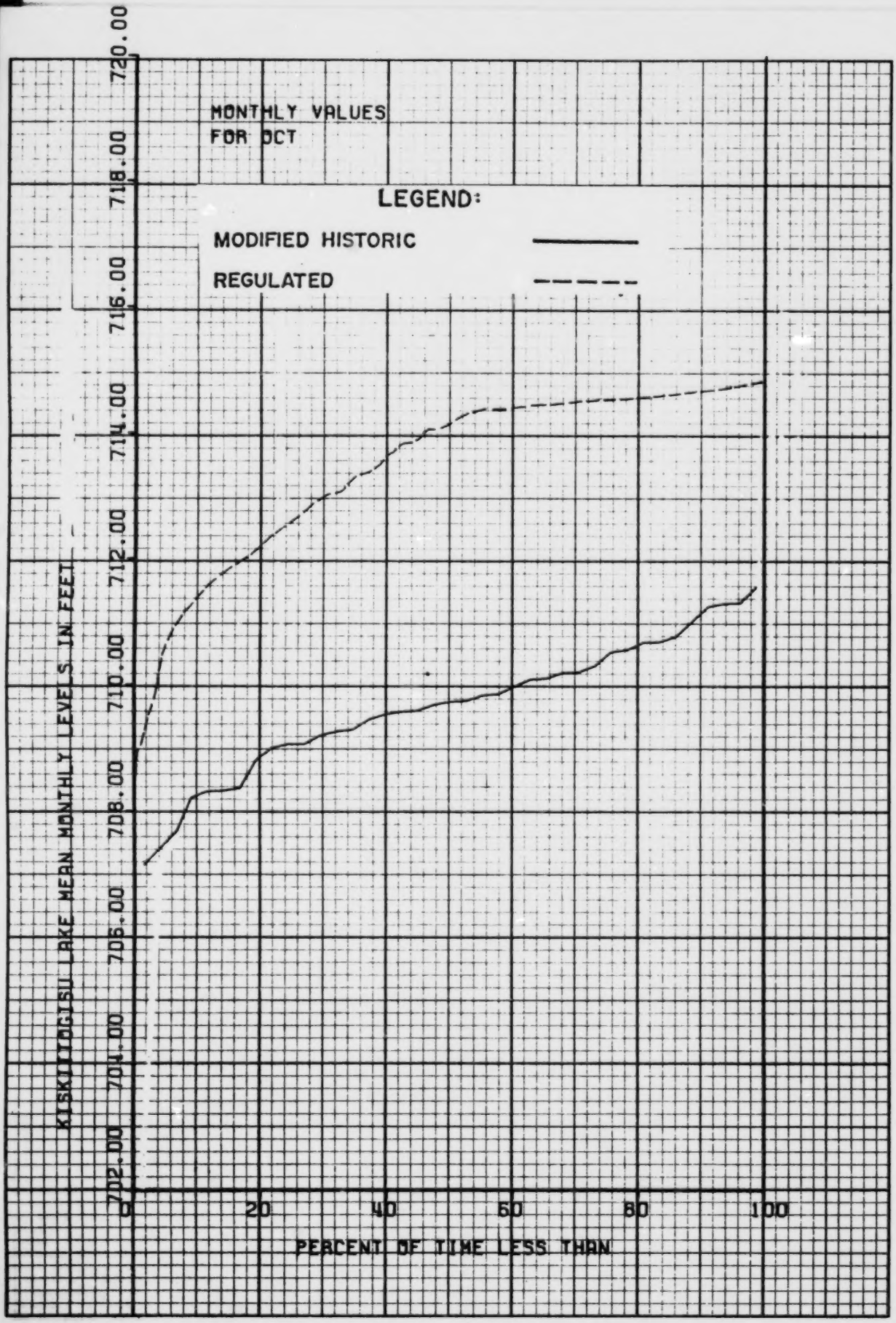

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITTOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
50
80
100
PERCENT OF TIME LESS THAN

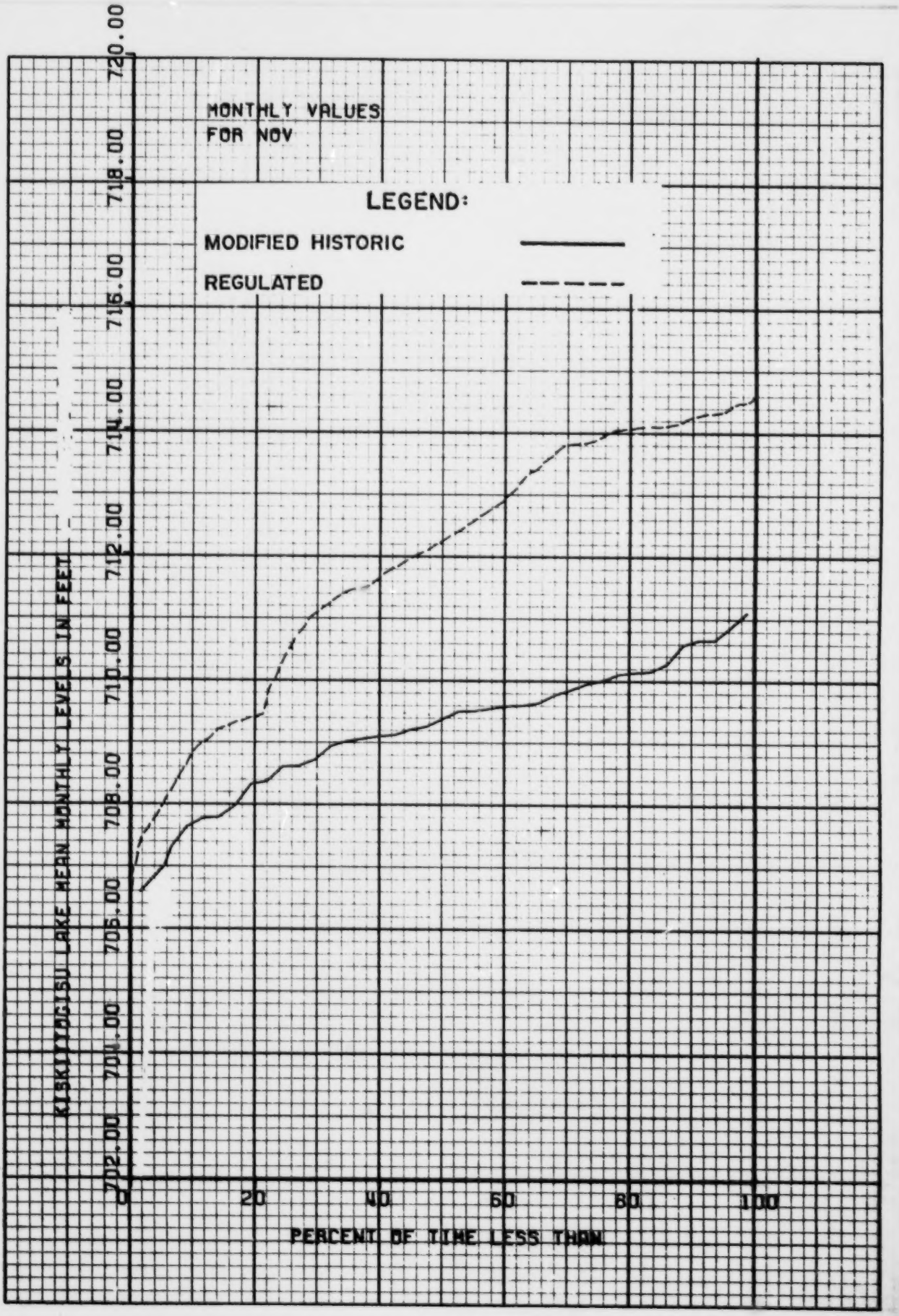

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.0
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

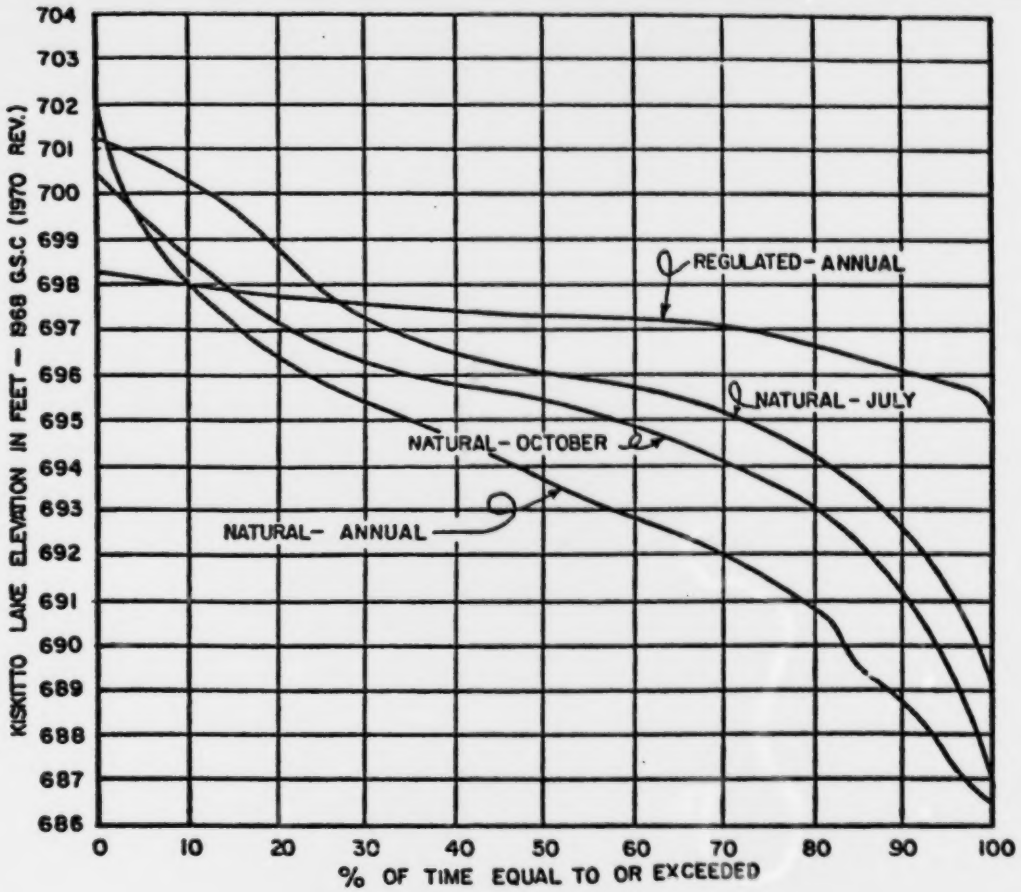

MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITTOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITTOGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
KISKITLAGISU LAKE MEAN MONTHLY LEVELS IN FEET
720.00
718.00
716.00
714.00
712.00
710.00
708.00
706.00
704.00
702.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

KISKITTO LAKE
LEVEL DURATION CURVE



NOTES:

1. BECAUSE WATER ELEVATIONS IN THE WEST CHANNEL OF THE NELSON RIVER ARE SUBJECT TO FLUCTUATIONS IN THE ORDER OF 5 FEET, DUE TO ICE JAMS, CALCULATED WATER LEVELS IN THE WINTER FOR KISKITTO LAKE ARE APPROXIMATE ONLY. THE DURATION CURVE FOR NATURAL CONDITIONS FOR ALL MONTHS IS BASED ON APPROXIMATED WINTER KISKITTO LEVELS ASSUMING ICE JAMMING IN THE WEST CHANNEL NELSON RIVER.
2. FULL SUPPLY LEVEL = 695 (CREST ELEVATION OF WEIR = 694).
3. REGULATED DURATION CURVES FOR JULY AND OCTOBER ARE ALMOST IDENTICAL TO REGULATED - ANNUAL

NOTED	
CIVIL	W.L.I.V.
ELECTRICAL	
MECHANICAL	
GEOTECHNICAL	
PROJECT	
CHIEF DESIGN	
APPROVED	

MANITOBA HYDRO
DESIGN DIVISION

LAKE WINNIPEG REGULATION

KISKITTO – MINAGO
DRAINAGE CHANNEL & CONTROL
NATURAL & REGULATED
DURATION CURVES
KISKITTO LAKE 1921-1970
10' WIDE CONTROL STRUCTURE

DATE	APRIL 20, 1972	SCALE	AS SHOWN	
DRAWN	J.C.	0510-A-9504		0
CHECKED	W.V.			

CROSS LAKE
LEVELS

CROSS LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	3	89	3	97	11	89	50	47	3	0	37	0	82	13	45	55	13	84	8	92	3	76	0	68
1 - 2	0	8	0	0	0	0	3	0	66	0	55	0	5	0	0	0	0	3	0	0	0	21	0	32
2 - 4	0	0	0	0	0	0	0	0	32	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	675.07	674.92	674.77	674.89	676.01	676.71	676.75	676.58	676.48	676.31	675.80	675.26	674.77
AVERAGE	677.31	676.92	676.72	676.83	678.58	679.79	680.15	680.13	679.84	679.49	678.78	677.93	678.54
MAXIMUM	680.56	679.57	678.97	679.89	681.77	684.41	685.09	684.26	683.36	683.05	682.62	681.31	685.09

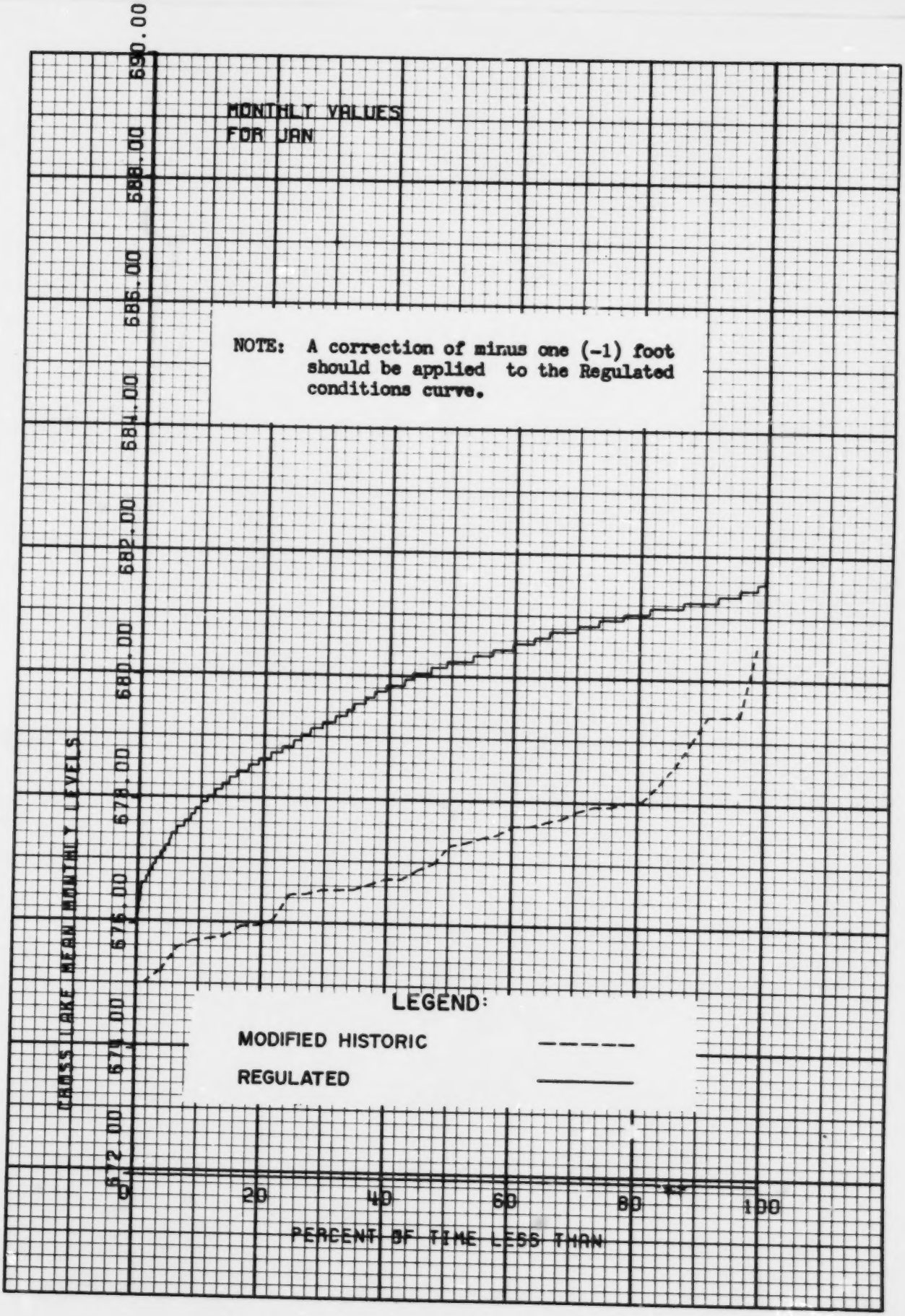
CROSS LAKE - REGULATED CONDITIONS

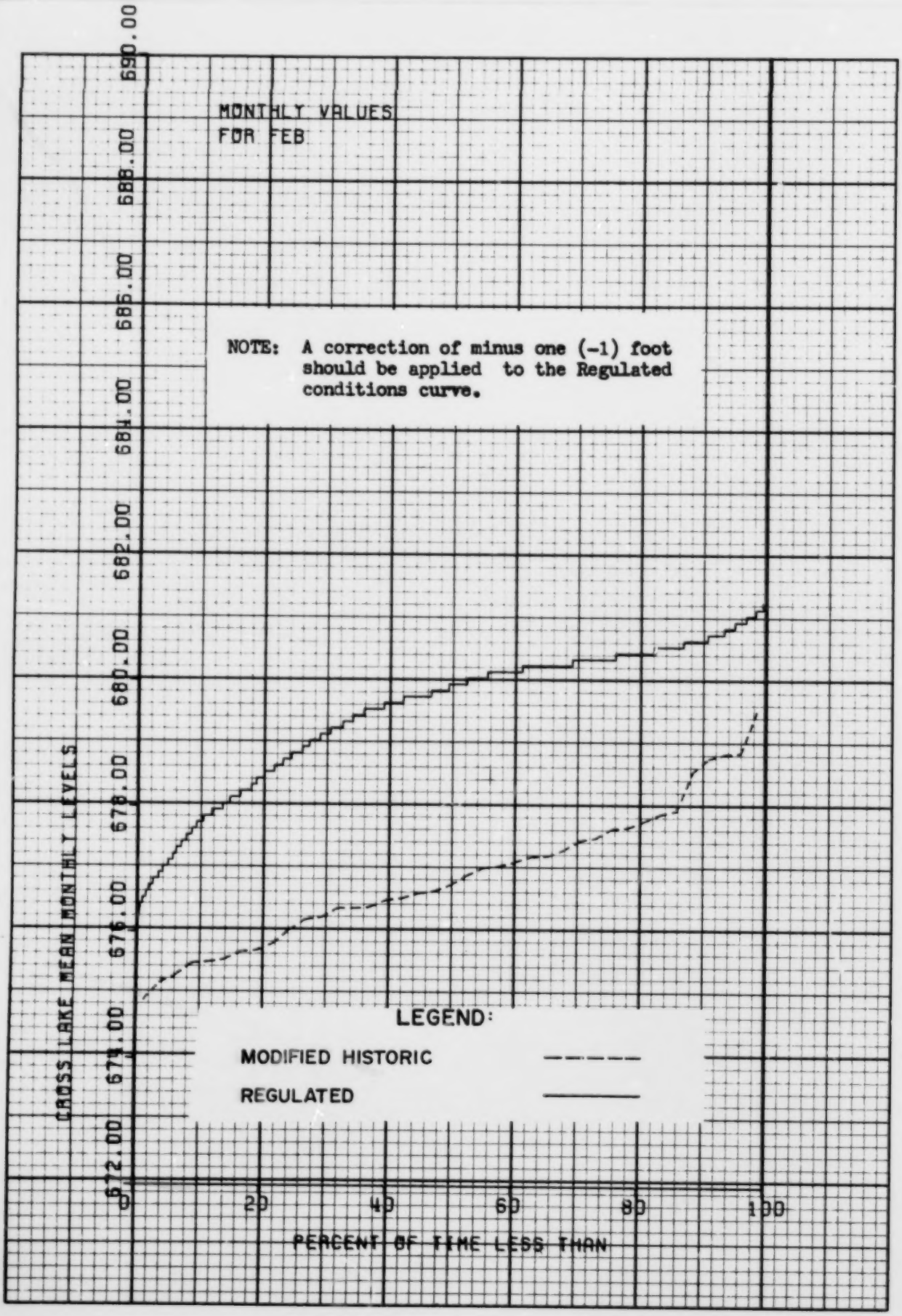
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

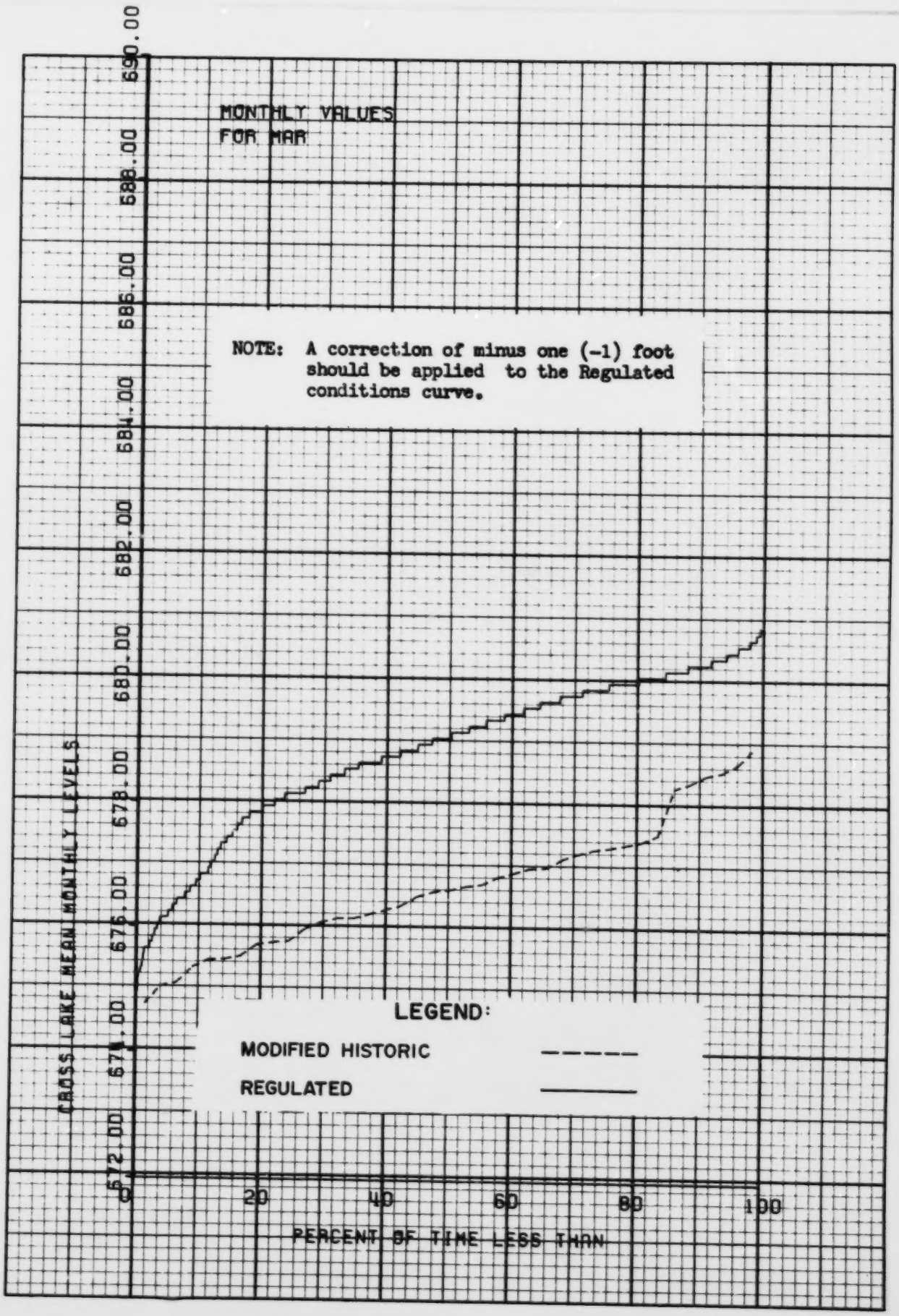
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	43	22	36	52	4	72	18	35	12	29	14	31	21	32	31	19	34	16	45	19	35	16	26	15
1 - 2	12	19	0	11	0	22	1	39	16	23	12	9	8	12	6	14	14	14	16	9	19	5	27	4
2 - 4	0	4	0	1	0	2	0	7	15	3	22	6	13	9	6	18	4	14	4	5	23	1	26	2
4 - 6	0	0	0	0	0	0	0	0	2	0	6	0	3	2	0	6	0	4	0	2	1	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

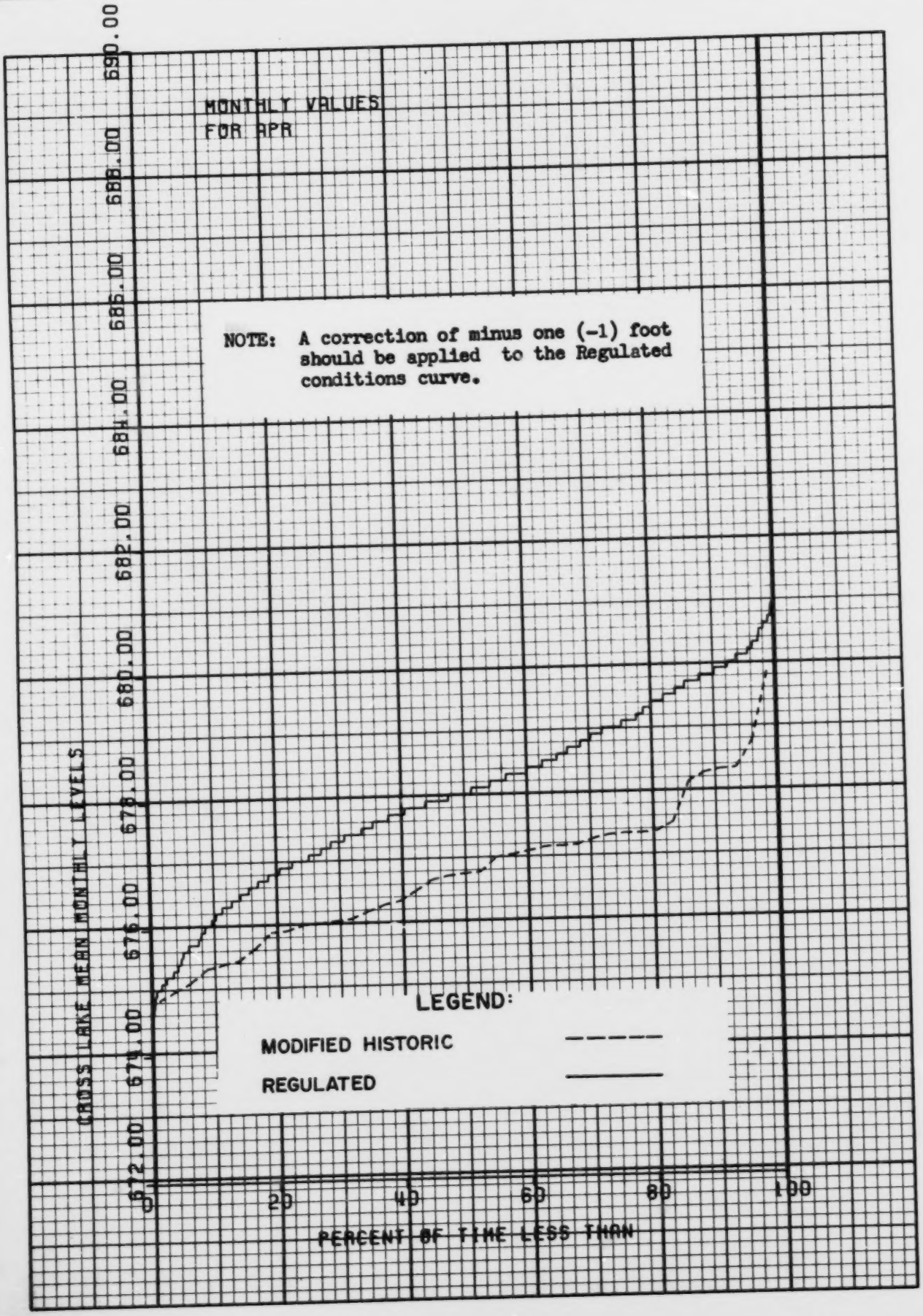
MEAN MONTHLY LEVELS IN FEET

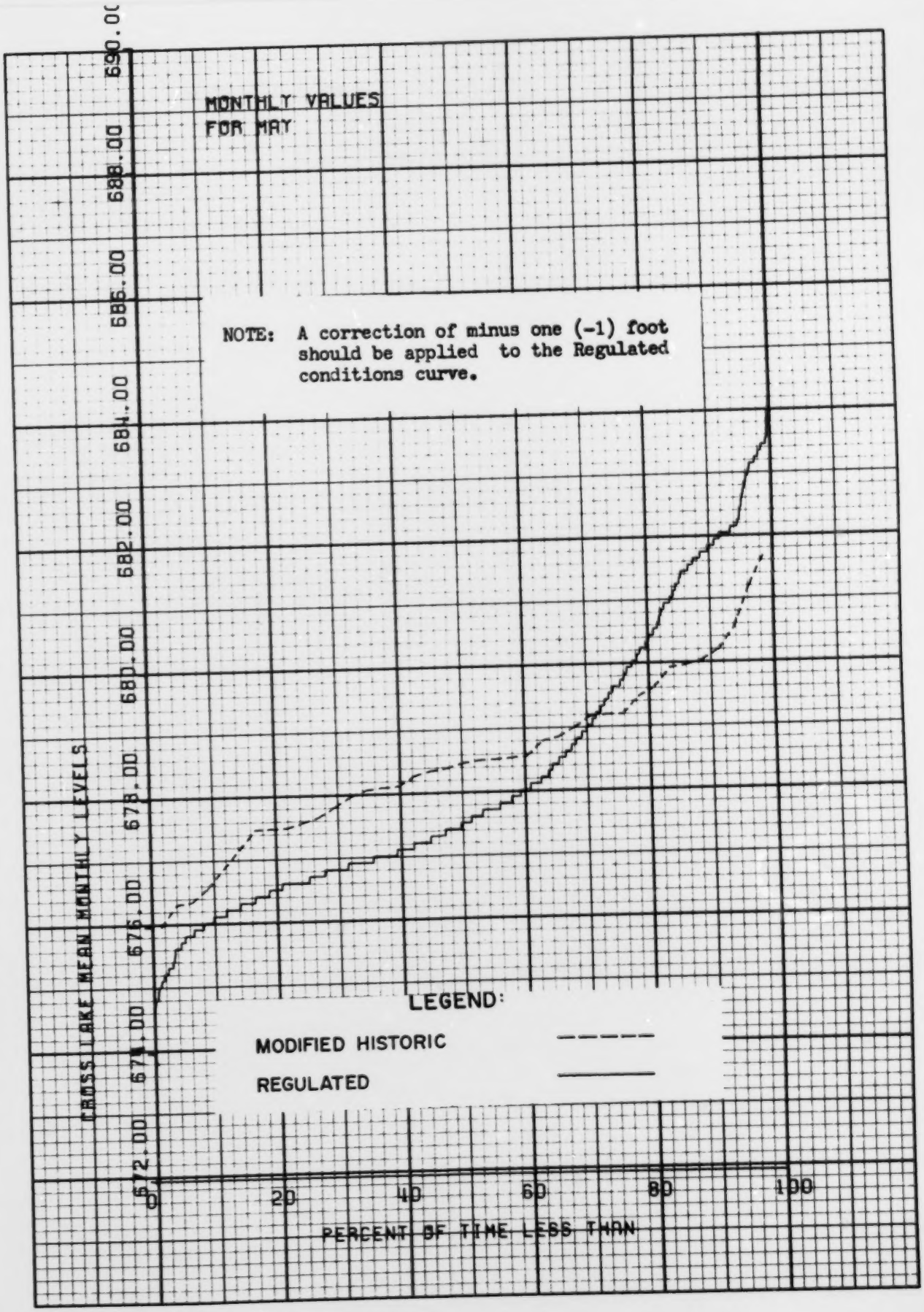
	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	675.20	675.20	674.00	673.60	673.80	673.90	673.60	673.40	673.80	673.90	673.60	674.40	673.40
AVERAGE	678.90	678.59	677.90	677.09	677.32	678.04	678.12	677.41	676.99	677.11	678.02	679.01	677.88
MAXIMUM	680.80	680.30	679.90	680.00	683.30	686.30	686.50	685.80	685.00	683.10	684.40	681.80	686.50

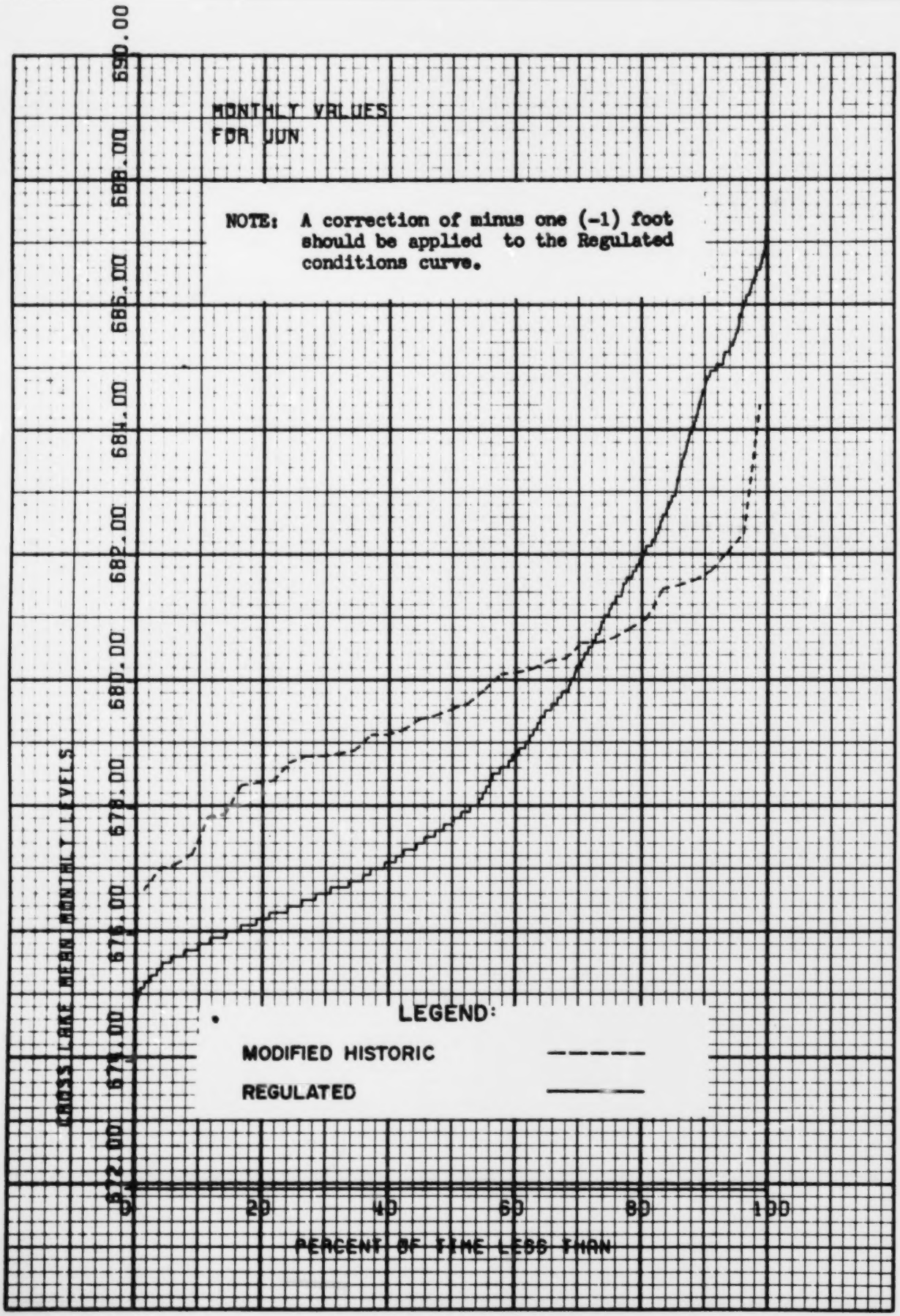

MONTHLY VALUES
FOR JAN
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
CAYUGA LAKE MEAN MONTHLY LEVELS
LEGEND:
MODIFIED HISTORIC
REGULATED
20
40
60
80
100
PERCENT OF TIME LESS THAN

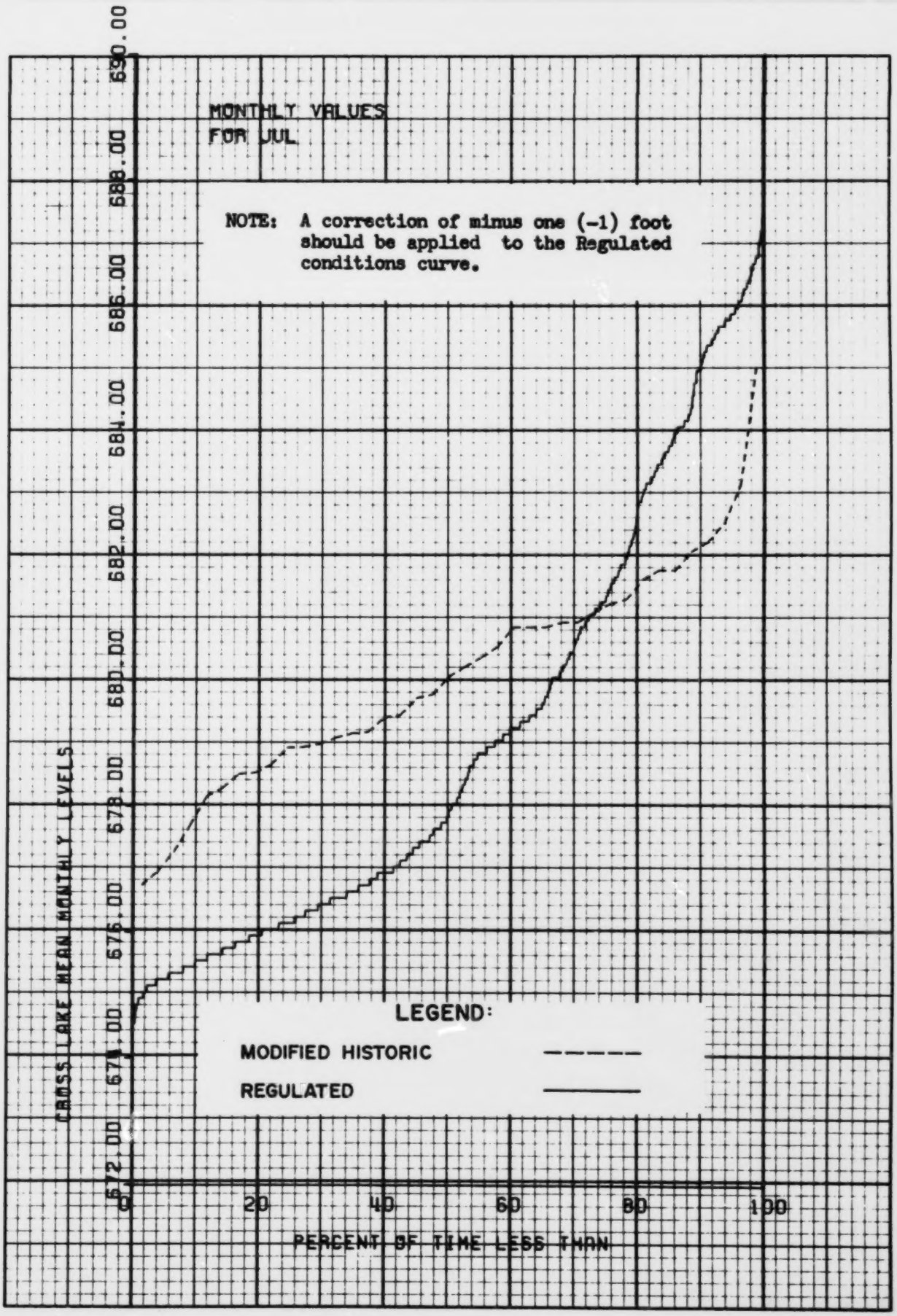

MONTHLY VALUES
FOR FEB
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

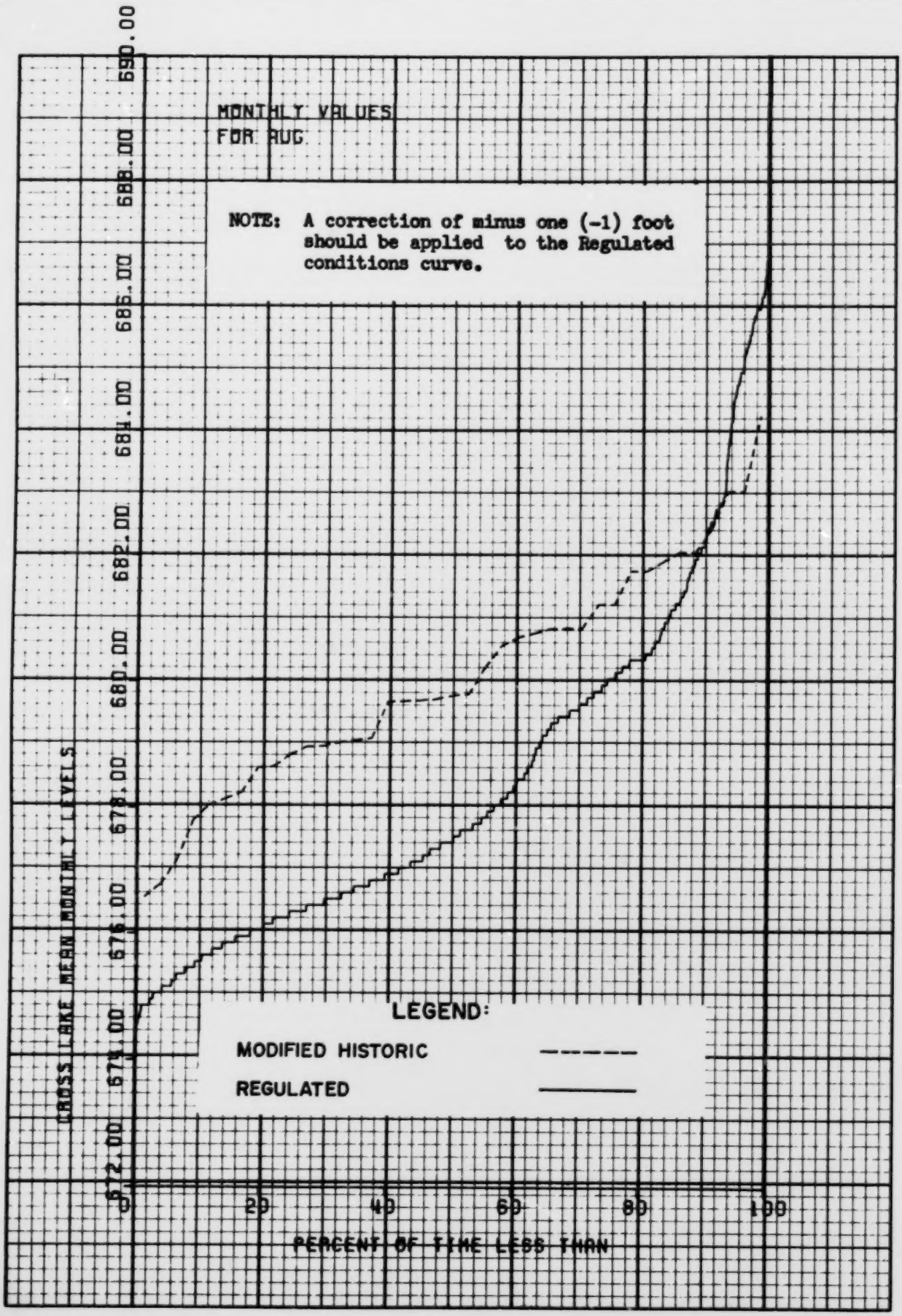

690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
MONTHLY VALUES
FOR MAR
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
CROSS LAKE MEAN MONTHLY LEVELS
LEGEND:
MODIFIED HISTORIC
REGULATED
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

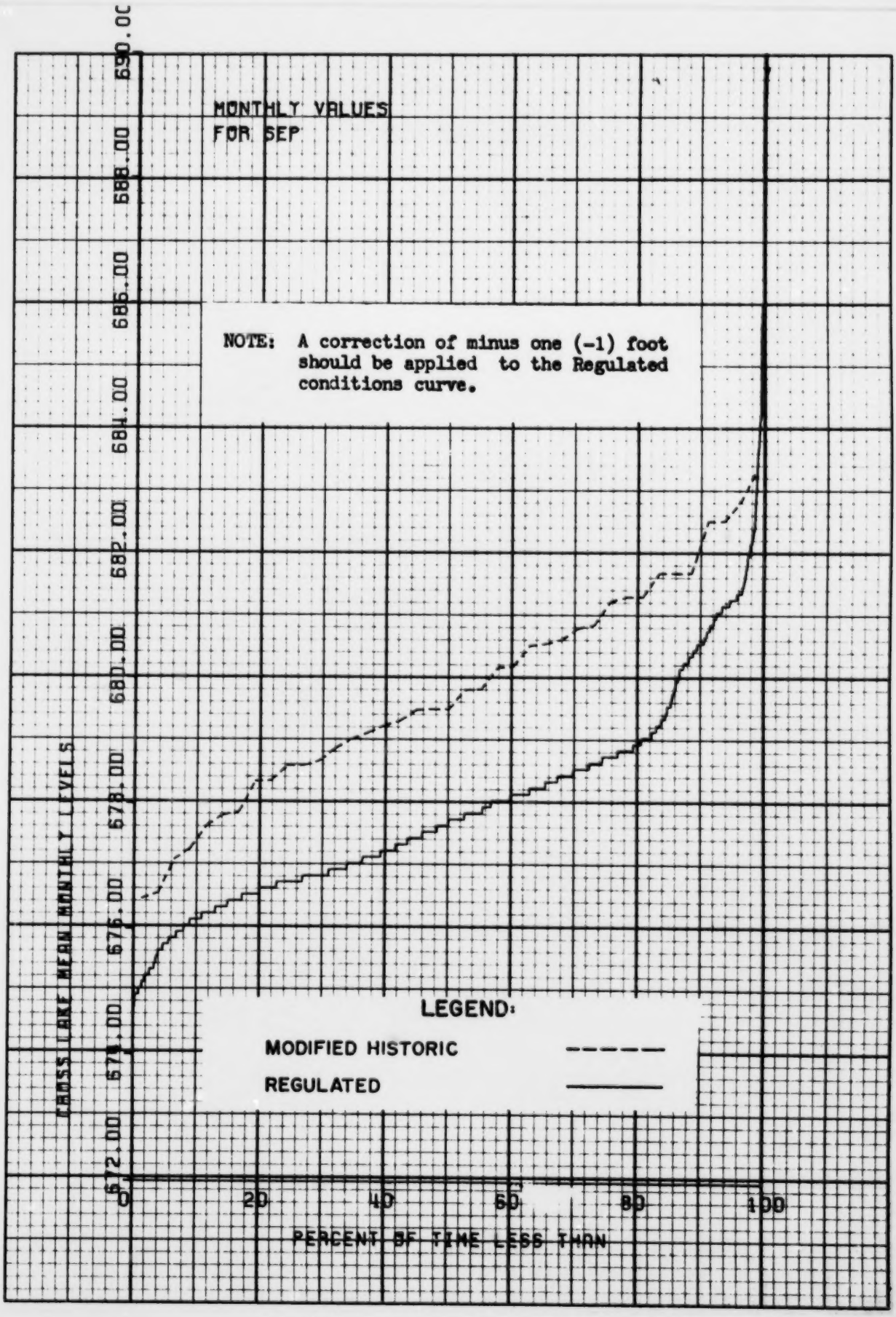

MONTHLY VALUES
FOR APR
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

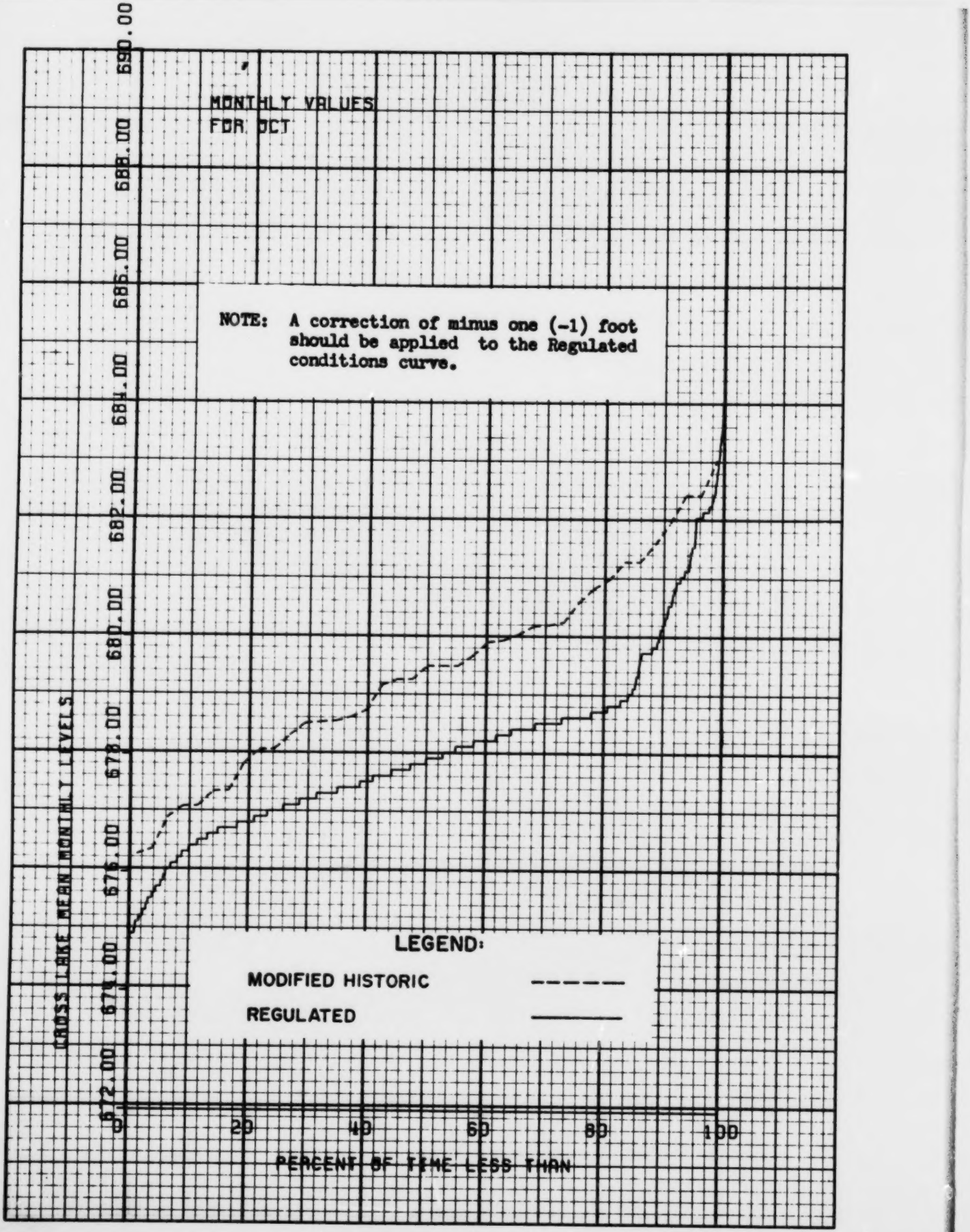

690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
CROSS LAKE MEAN MONTHLY LEVELS
MONTHLY VALUES
FOR MAY
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

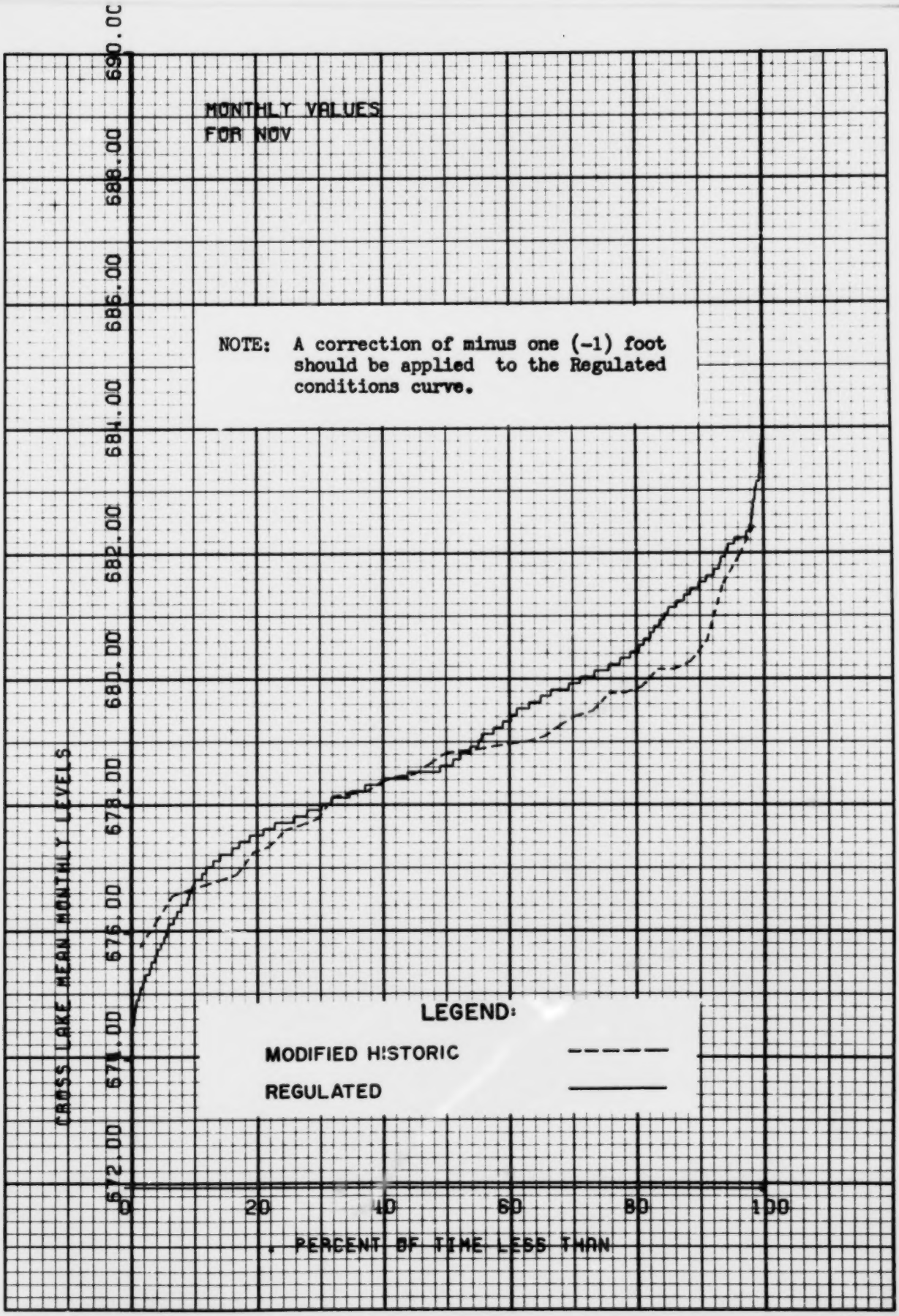

MONTHLY VALUES
FOR JUN.
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
672.00
676.00
680.00
684.00
688.00
692.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

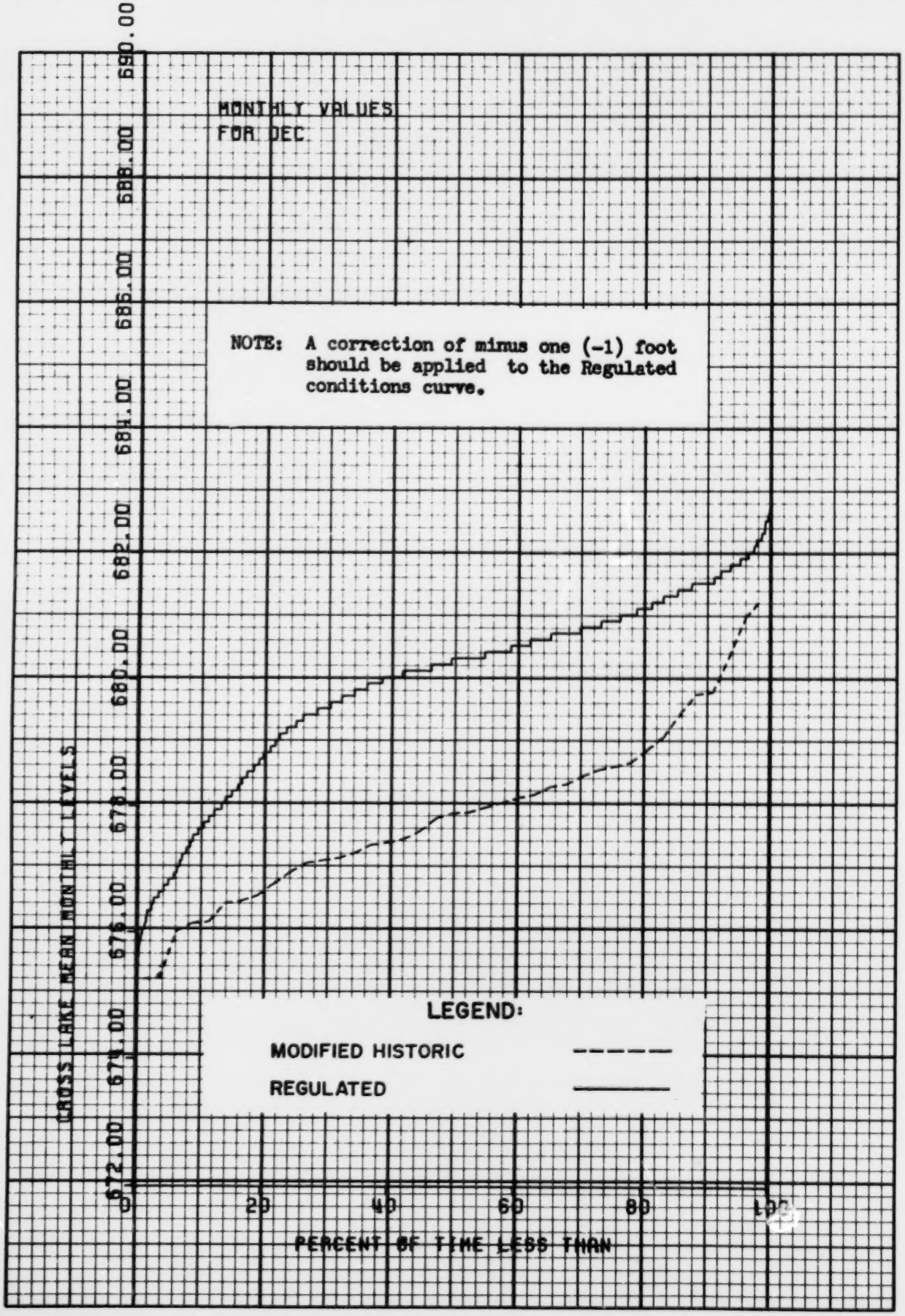

MONTHLY VALUES
FOR JUL
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CAYUGA LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
CROSS LAKE MEAN MONTHLY LEVELS
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED


MONTHLY VALUES
FOR NOV
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
NOTE: A correction of minus one (-1) foot should be applied to the Regulated conditions curve.
LEGEND:
MODIFIED HISTORIC
REGULATED
CROSS LAKE MEAN MONTHLY LEVELS
690.00
688.00
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SECTION 3

DIVERSION ROUTE STUDY AREA

NOTIGI CONTROL STRUCTURE
FLOWS

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

NOTIGI CONTROL STRUCTURE FLOWS HYDROLOGIC PERIOD 1928 - 1966

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	8	92	5	95	8	92	74	26	100	0	84	16	8	92	11	89	24	76	13	87	6	94	5	95
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	109	96	90	98	731	585	183	341	134	183	207	158	90
AVERAGE	401	339	297	332	2200	2865	2225	1490	1346	1065	833	581	1165
MAXIMUM	817	719	658	951	3985	5862	4364	4205	3583	2553	1648	1060	5862

SOUTH BAY FLOWS HYDROLOGIC PERIOD 1928-1966

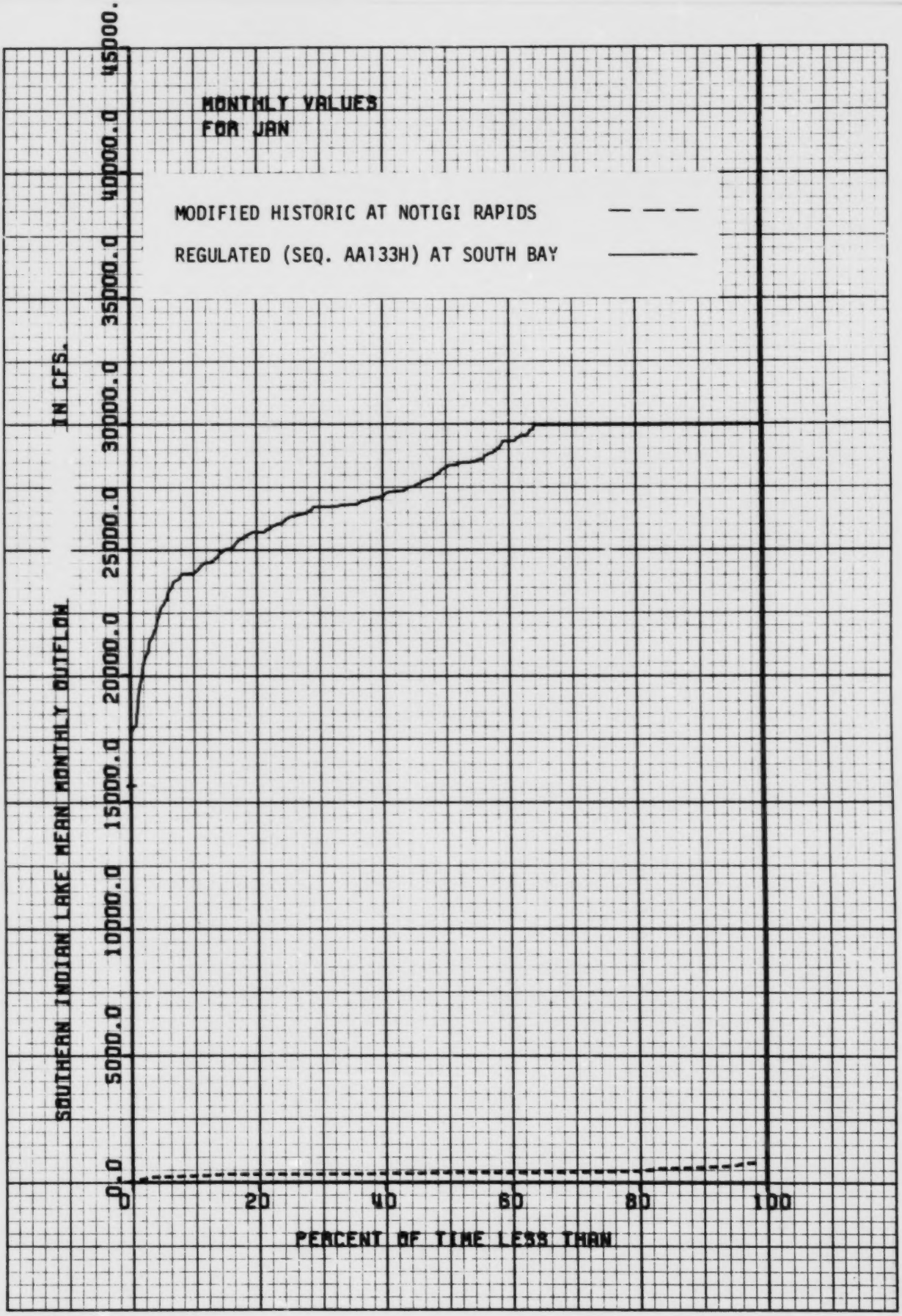
POST DIVERSION FLOWS

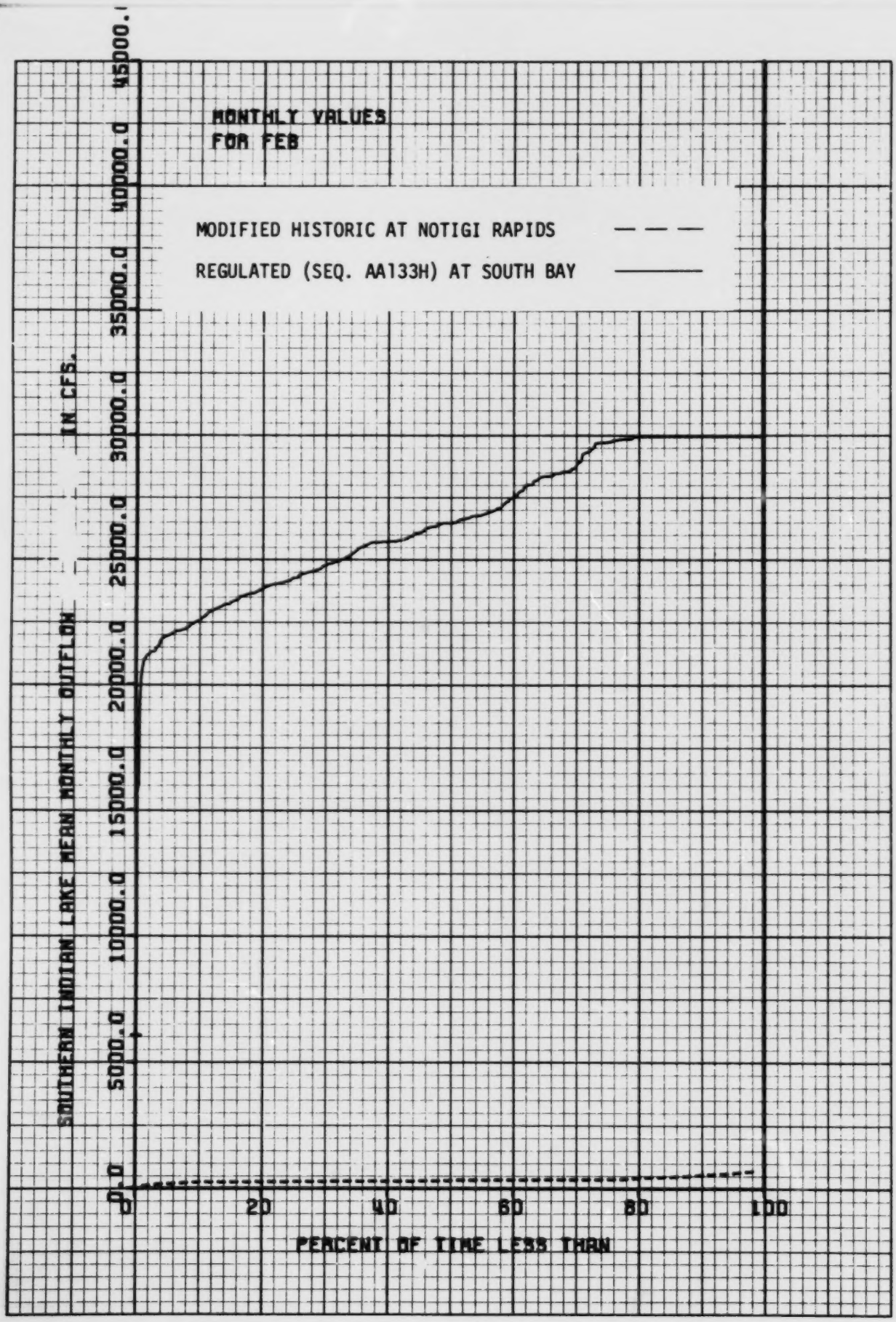
- FLUCTUATIONS IN PERCEN

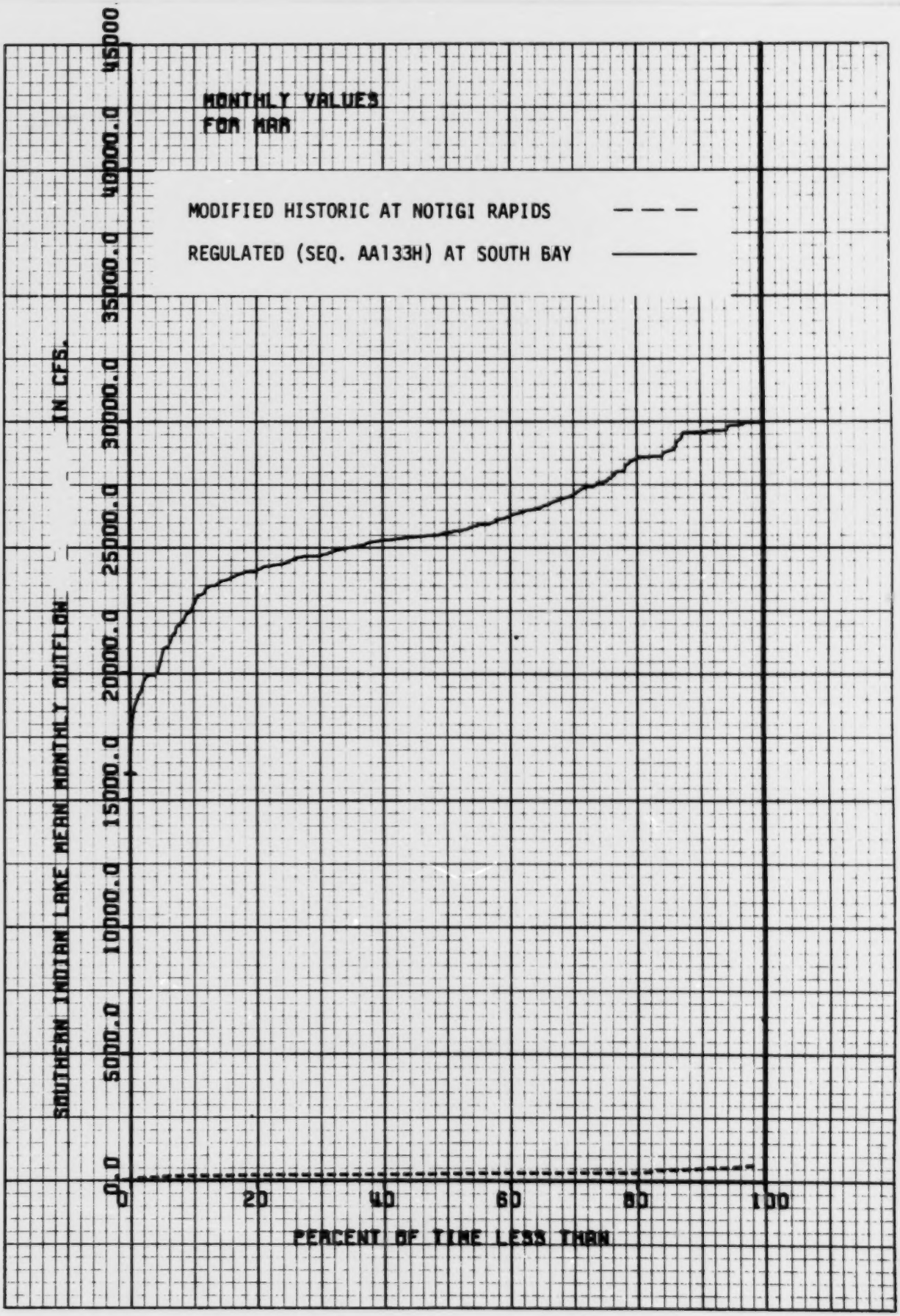
Range 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	54	42	31	65	34	57	33	48	44	35	12	33	100	0	100	0	94	3	84	8	74	21	53	38
5-10	2	2	1	2	0	8	6	9	12	3	4	51	0	0	0	0	0	2	0	7	2	2	0	8
10-20	0	0	0	1	1	1	1	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

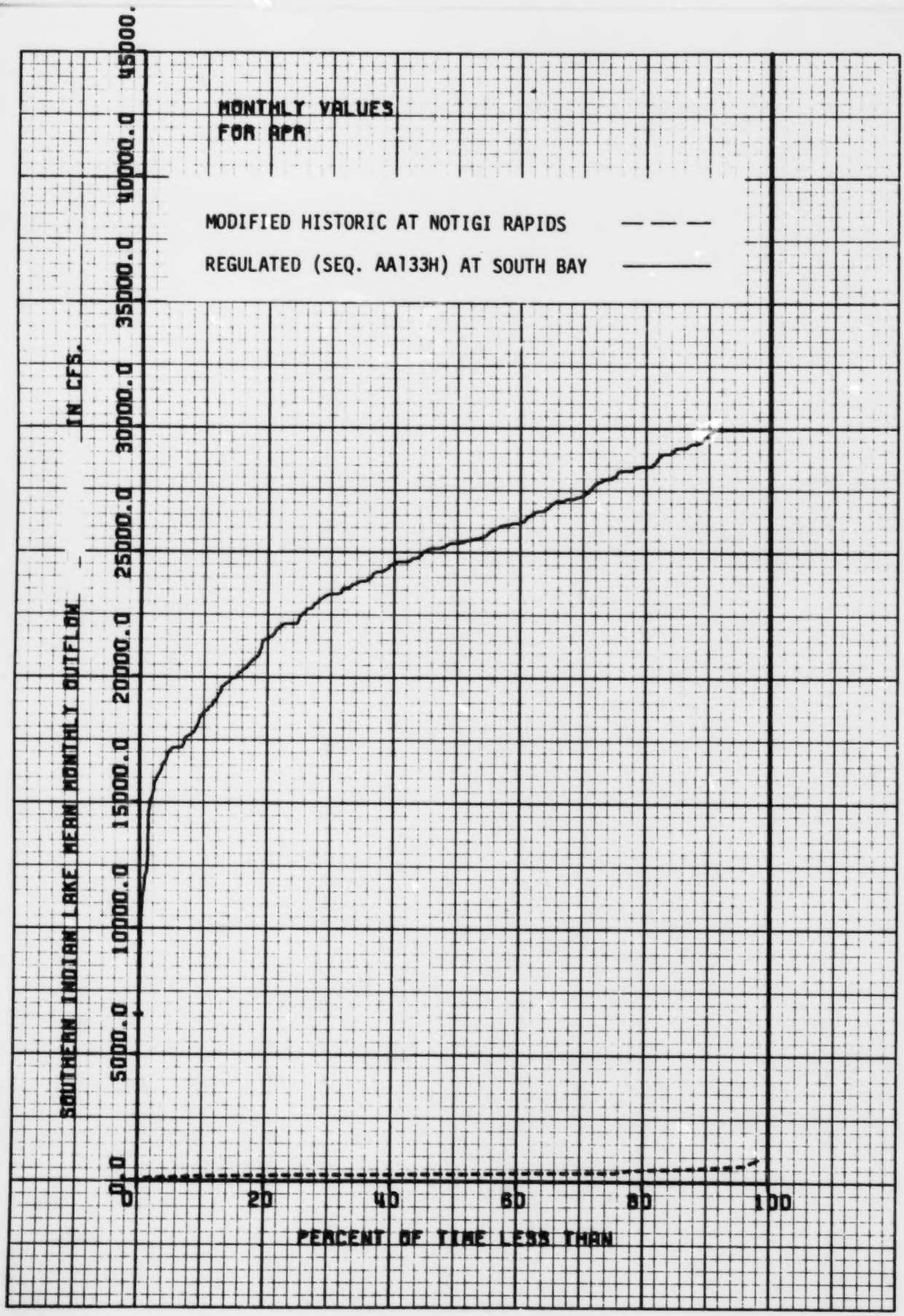
- FLOWS IN CFS -

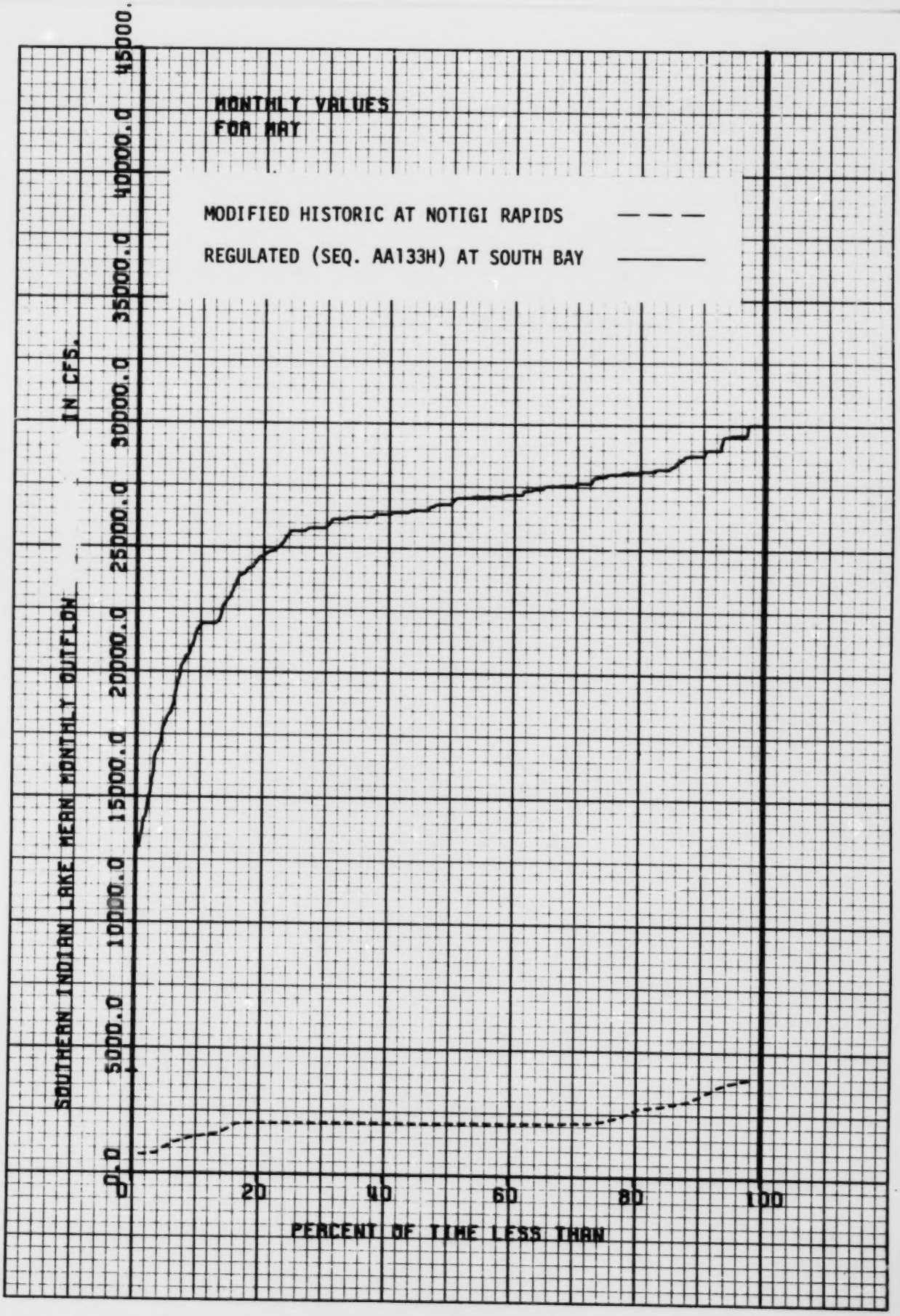
	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	15679	6033	16071	6638	4046	18124	22674	26706	22375	22306	18031	15135	4046
AVERAGE	27613	26521	25842	24746	25894	22392	25518	28491	29387	28932	28964	27931	26852
MAXIMUM	30000	30000	30000	30000	30000	28128	29703	30000	30000	30000	30000	30000	30000

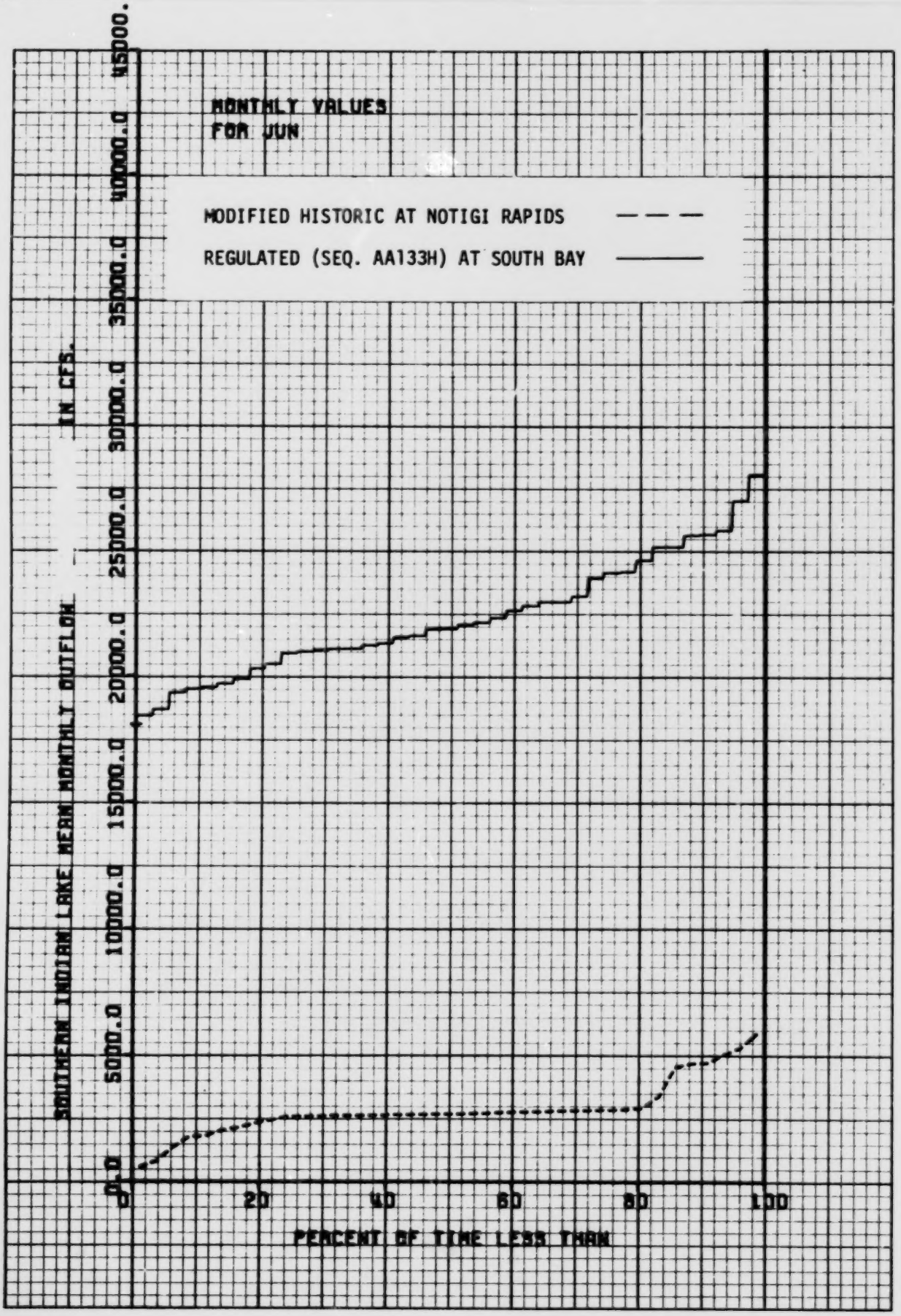

MONTHLY VALUES
FOR JAN
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHEAN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

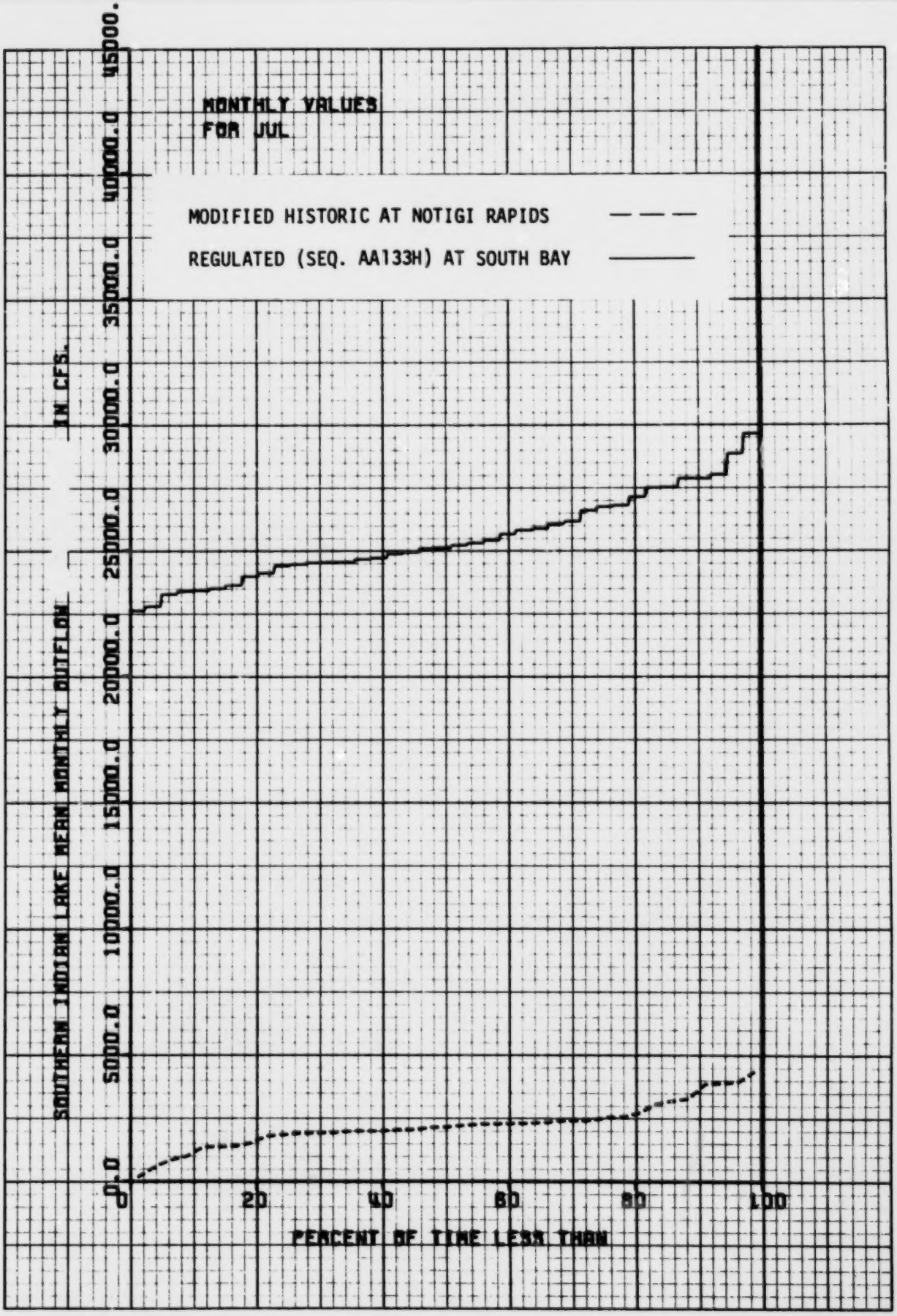

MONTHLY VALUES
FOR FEB
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

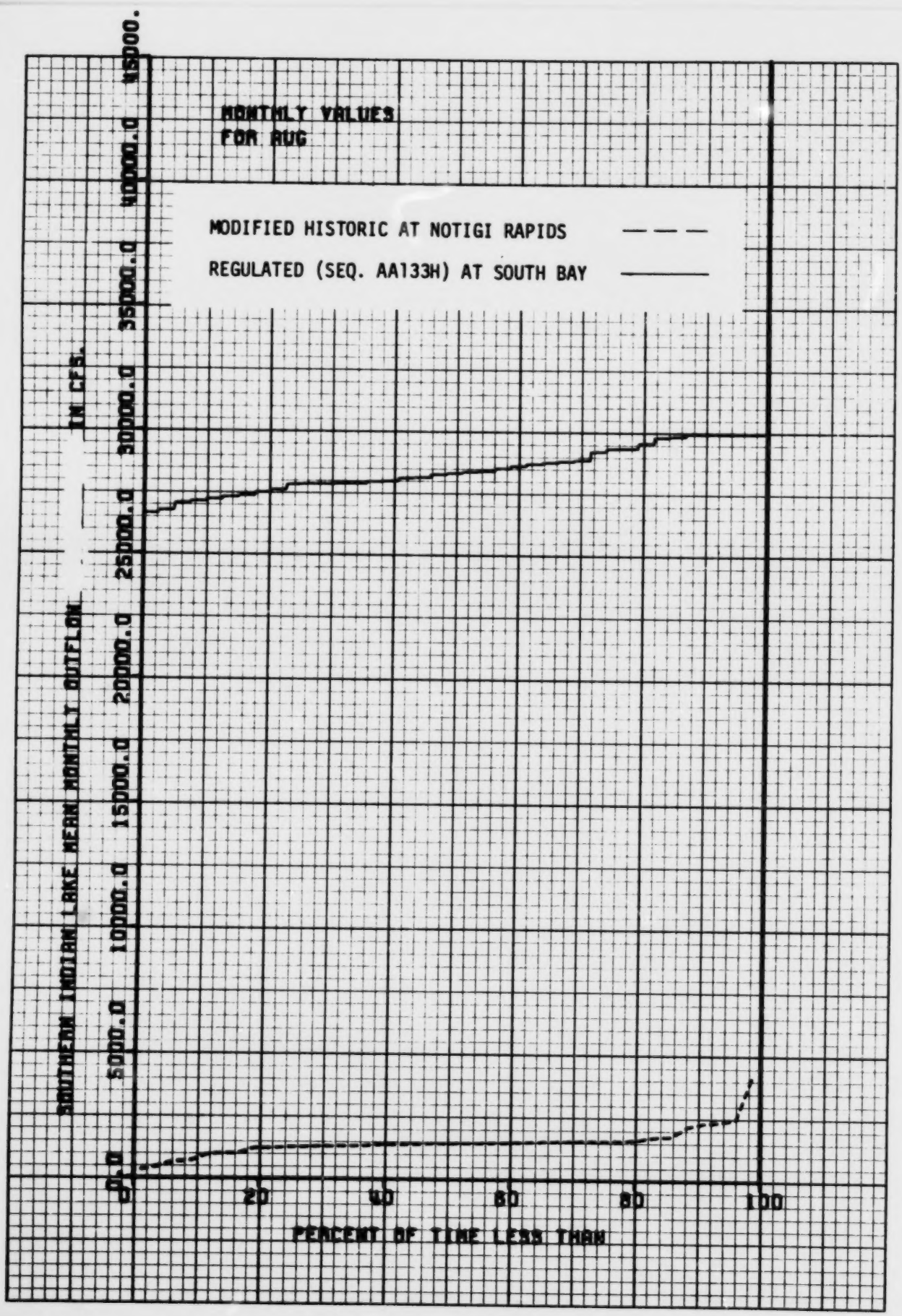

MONTHLY VALUES
FOR MAR
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

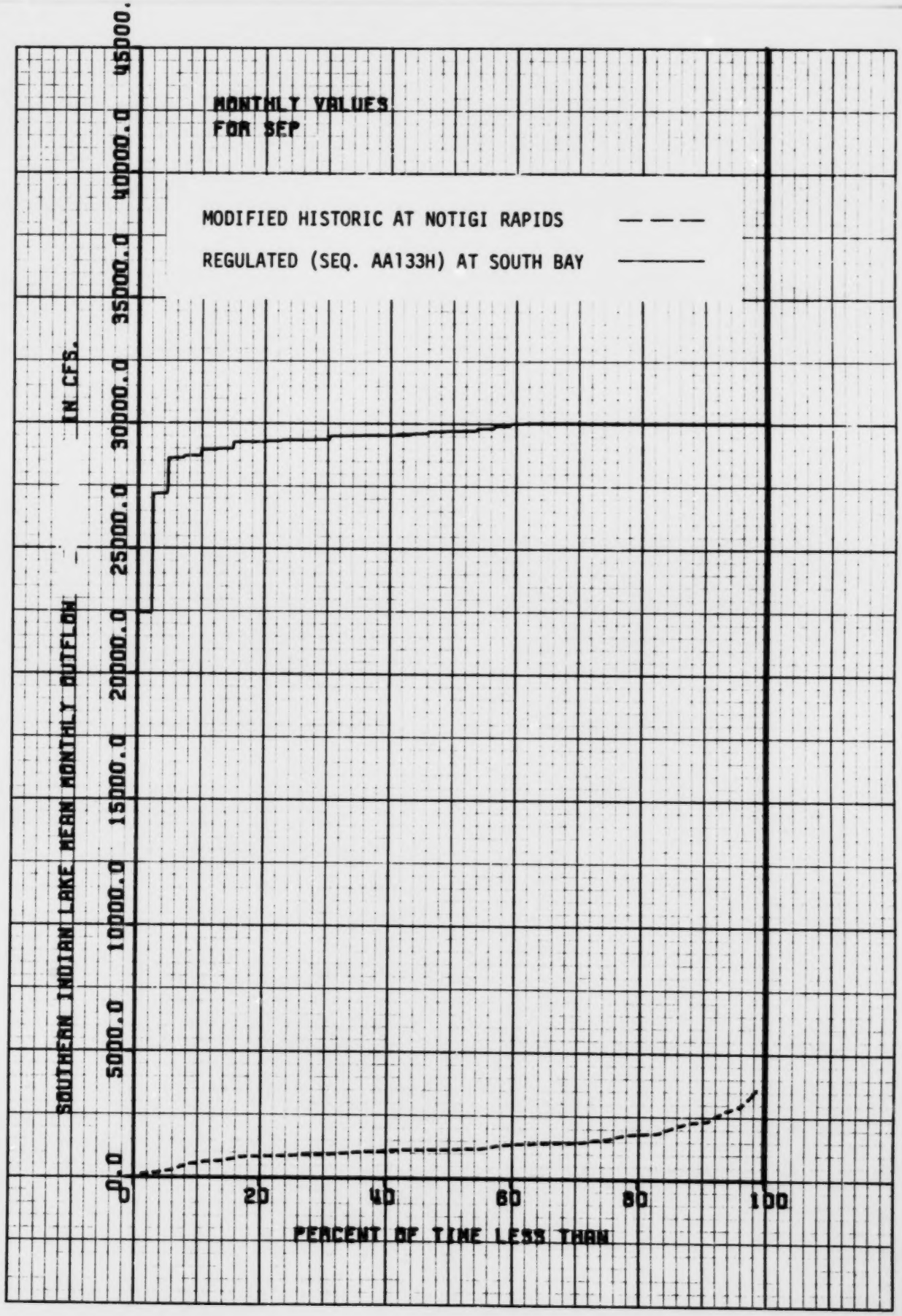

MONTHLY VALUES
FOR APR
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

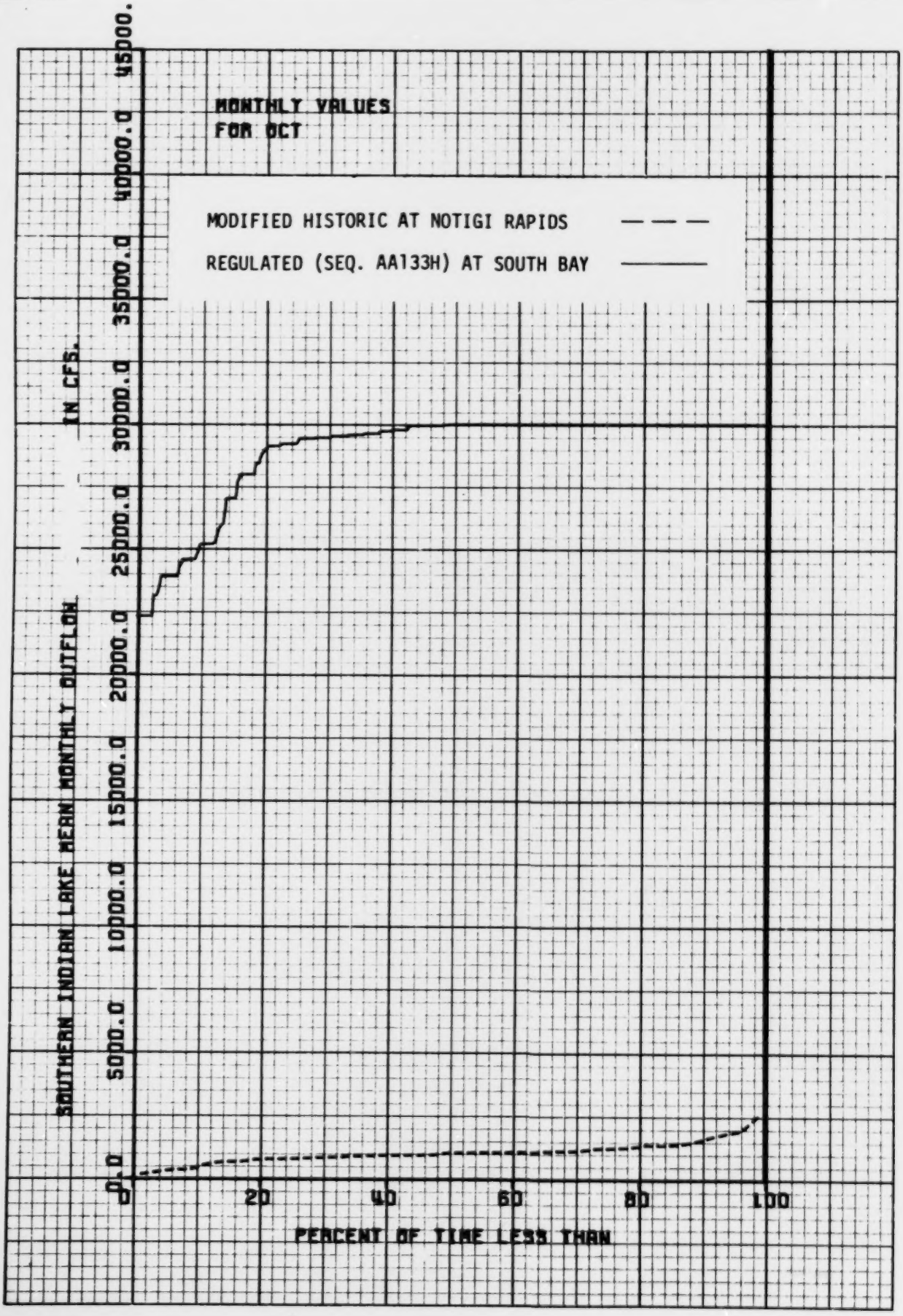

MONTHLY VALUES
FOR MAY
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

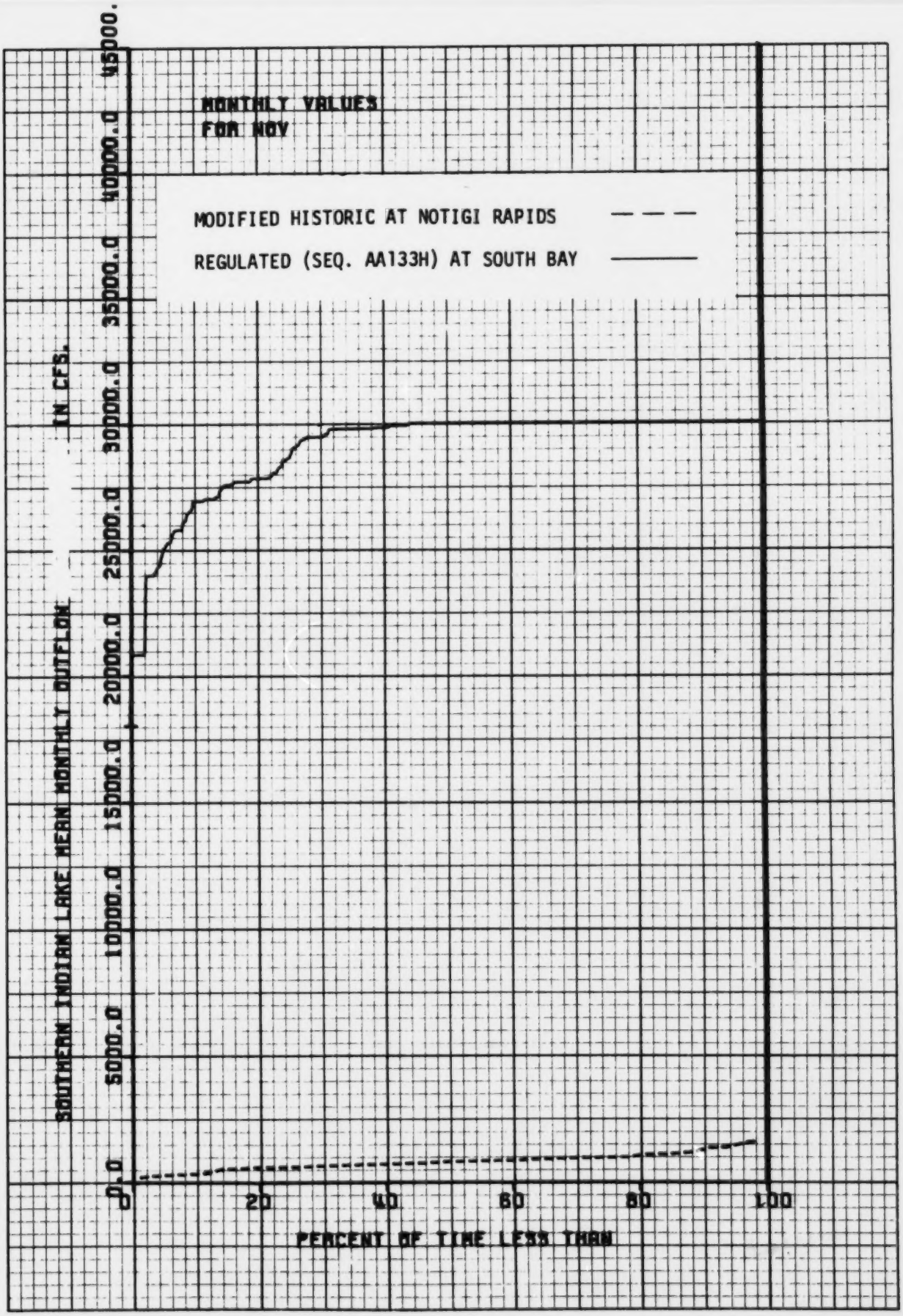

MONTHLY VALUES
FOR JUN
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

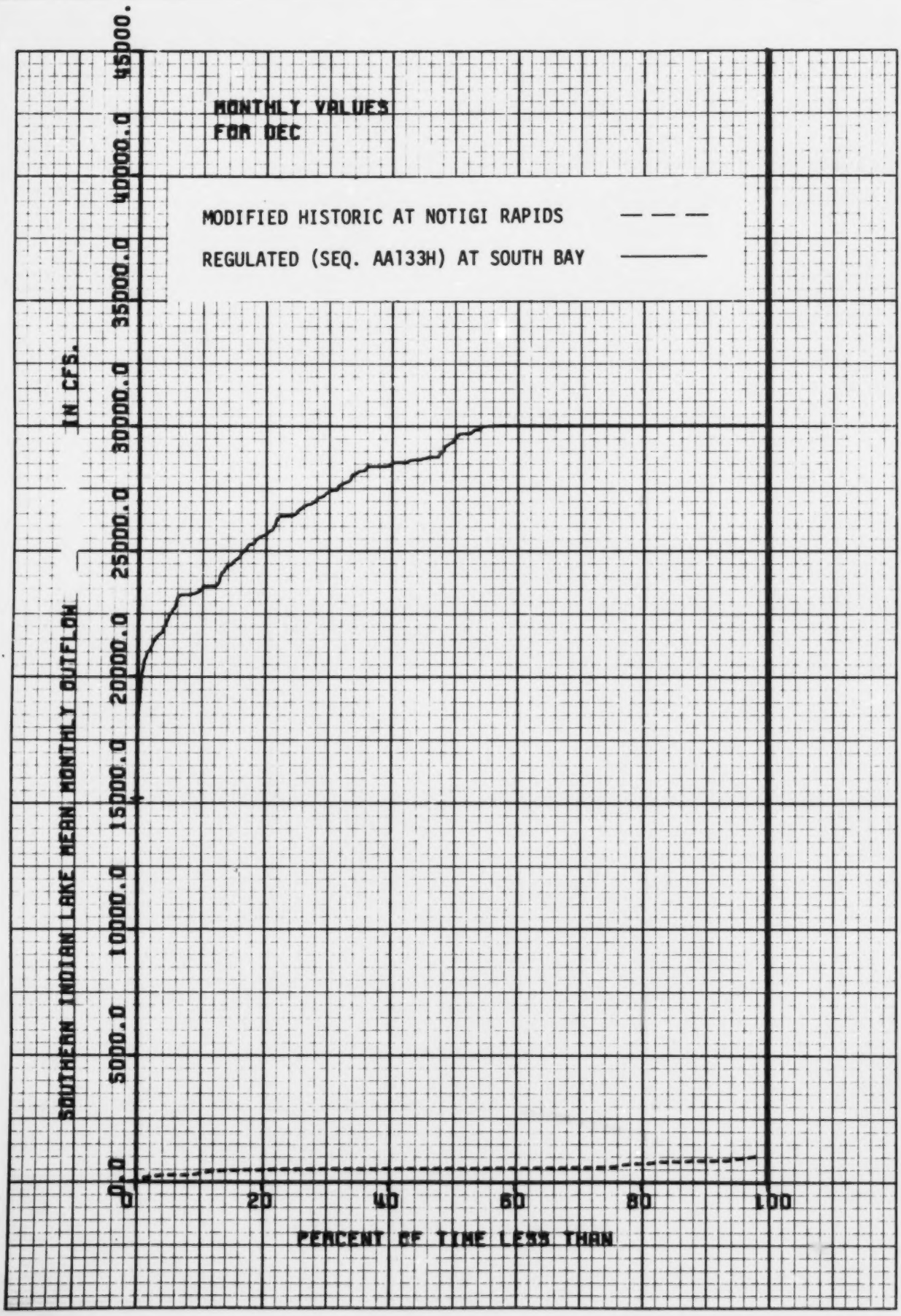

MONTHLY VALUES
FOR JUL
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
MODIFIED HISTORIC AT NOTIGI RAPIDS
REGULATED (SEQ. AA133H) AT SOUTH BAY
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW
IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

NOTIGI CONTROL STRUCTURE FLOWS HYDROLOGIC PERIOD 1912 - 1967

Modified Historic Flows

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	8	92	5	95	8	92	74	26	100	0	84	16	8	92	11	89	24	76	13	87	6	94	5	95
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

													ANNUAL
MINIMUM	109	96	90	98	731	585	183	341	134	183	207	158	90
AVERAGE	400	342	302	332	2139	2825	2195	1476	1296	1031	796	571	1146
MAXIMUM	817	719	658	951	3985	5862	4364	4205	3583	2553	1648	1060	5862

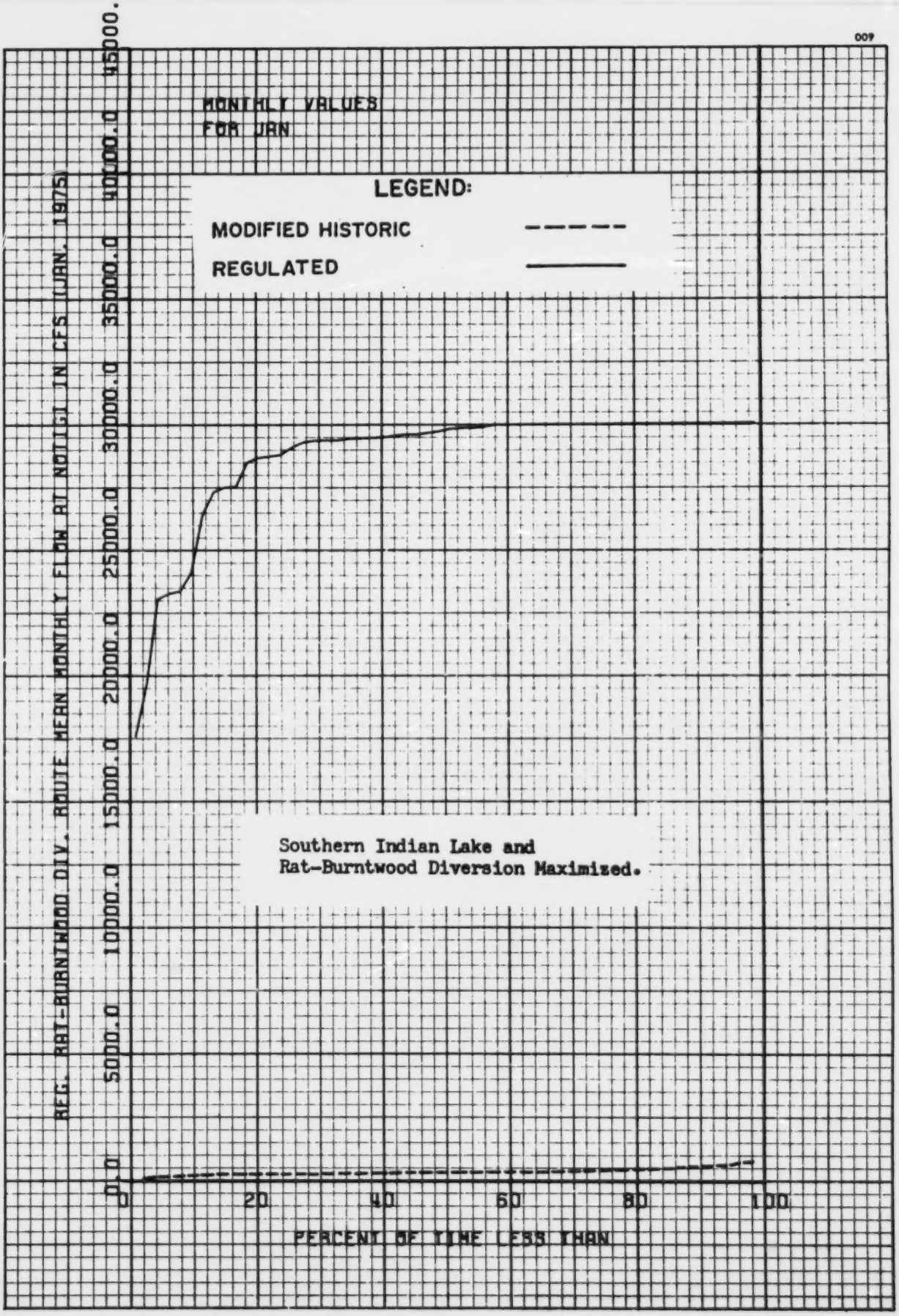
Post Diversion Flows

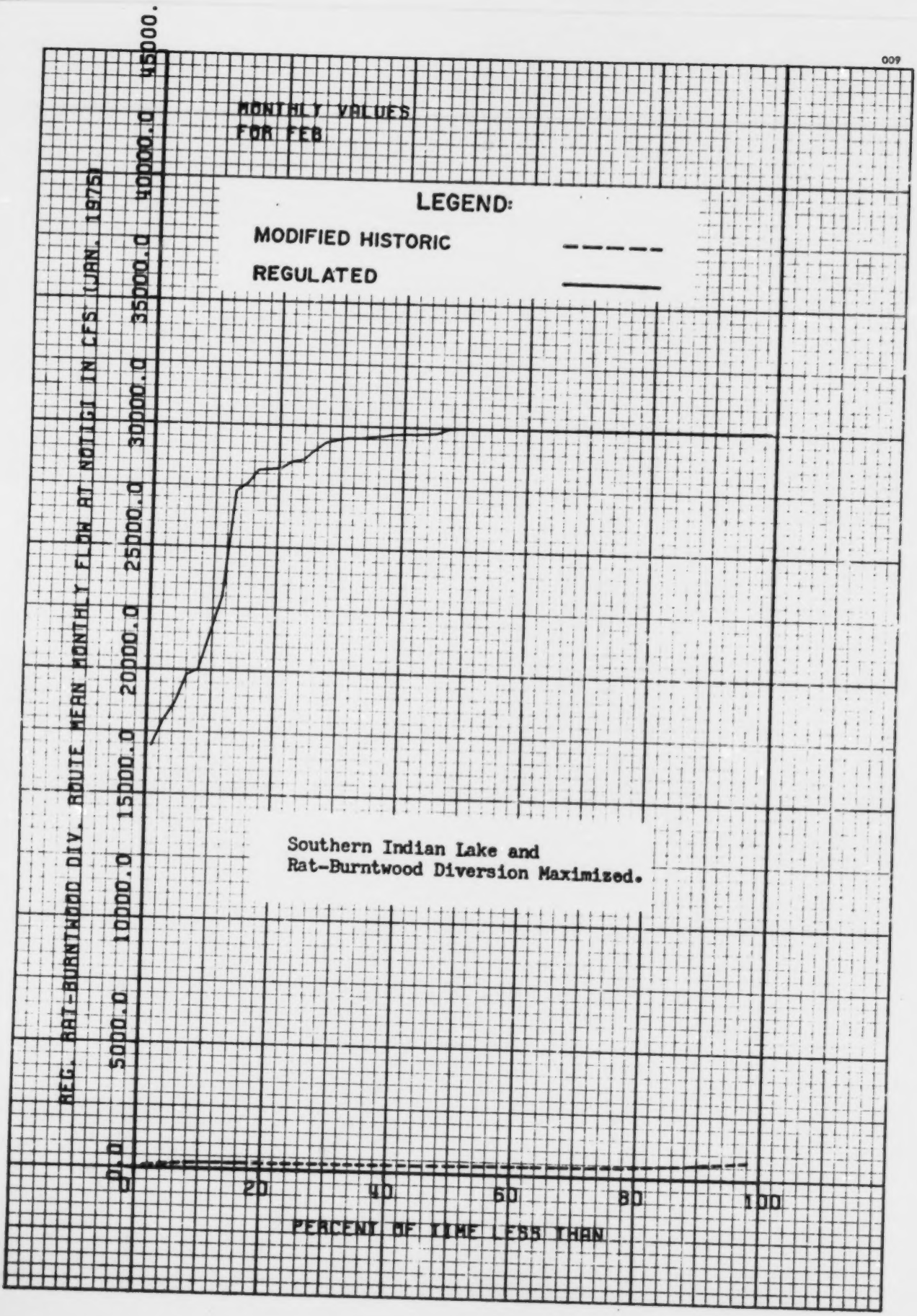
- FLUCTUATIONS IN PERCENT -

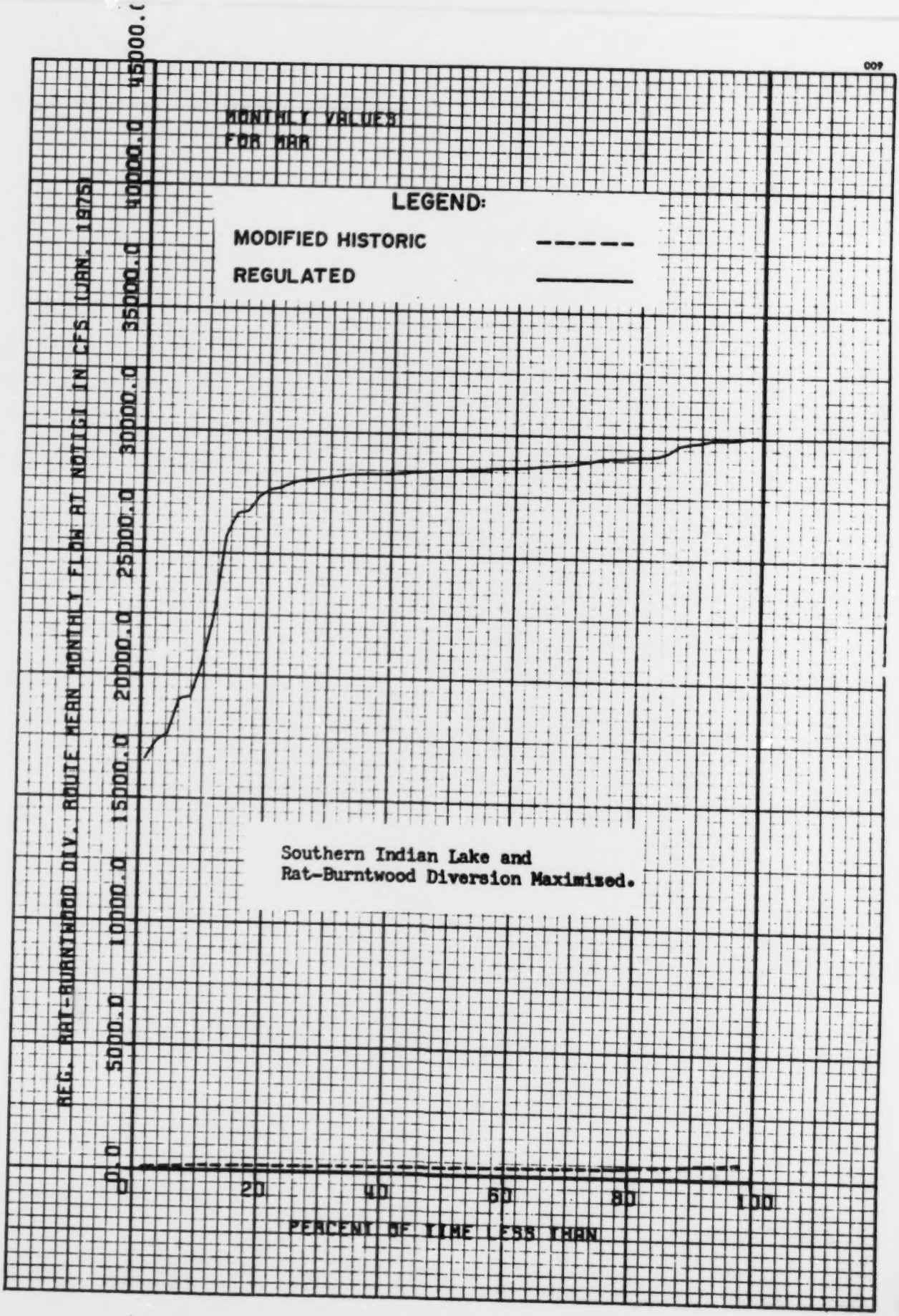
Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	22	73	50	48	16	84	14	86	75	25	23	63	93	7	86	14	46	50	57	43	55	45	38	55
5-10	5	0	0	2	0	0	0	0	0	0	9	5	0	0	0	0	0	4	0	0	0	0	0	7
10-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

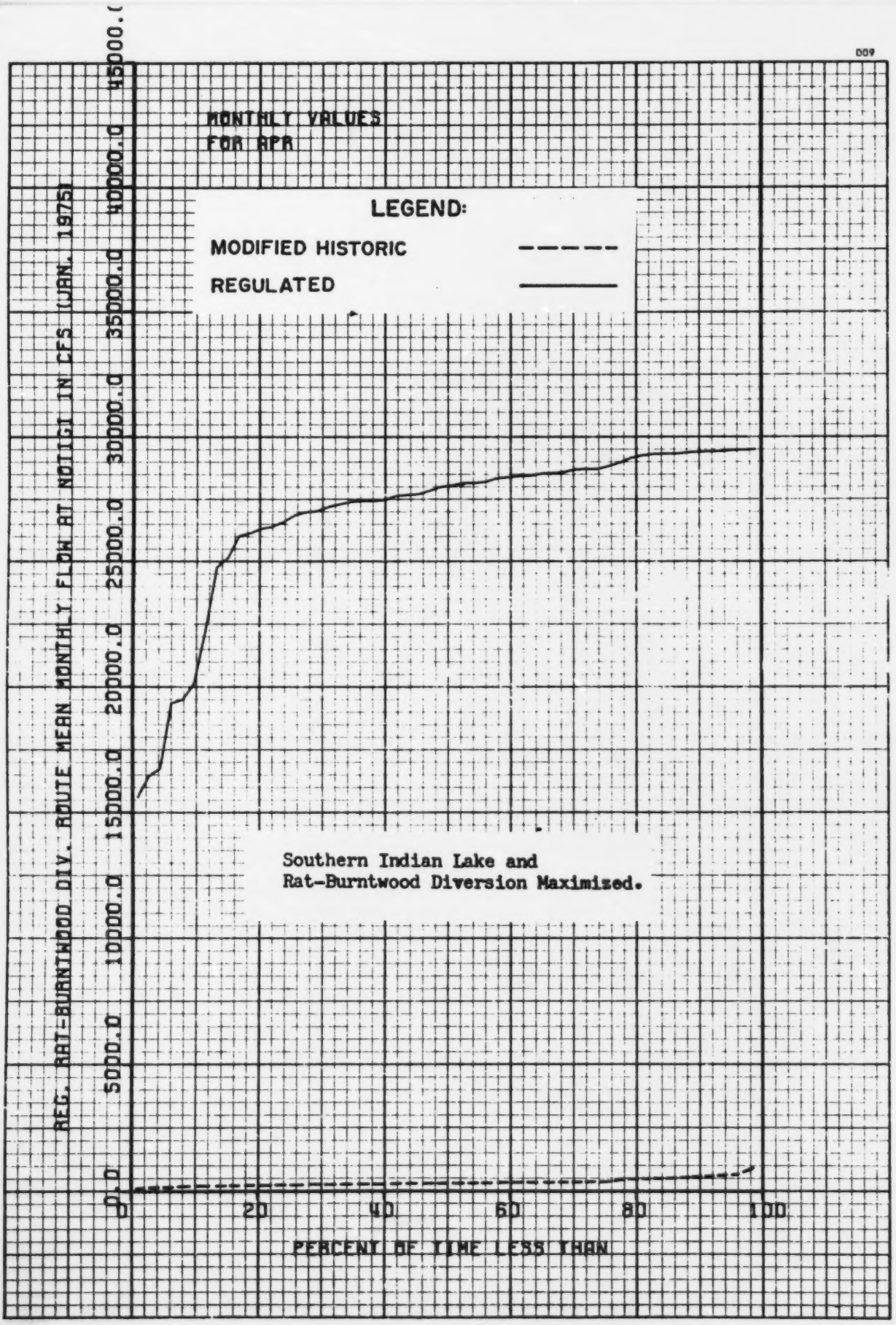
- FLOWS IN CFS -

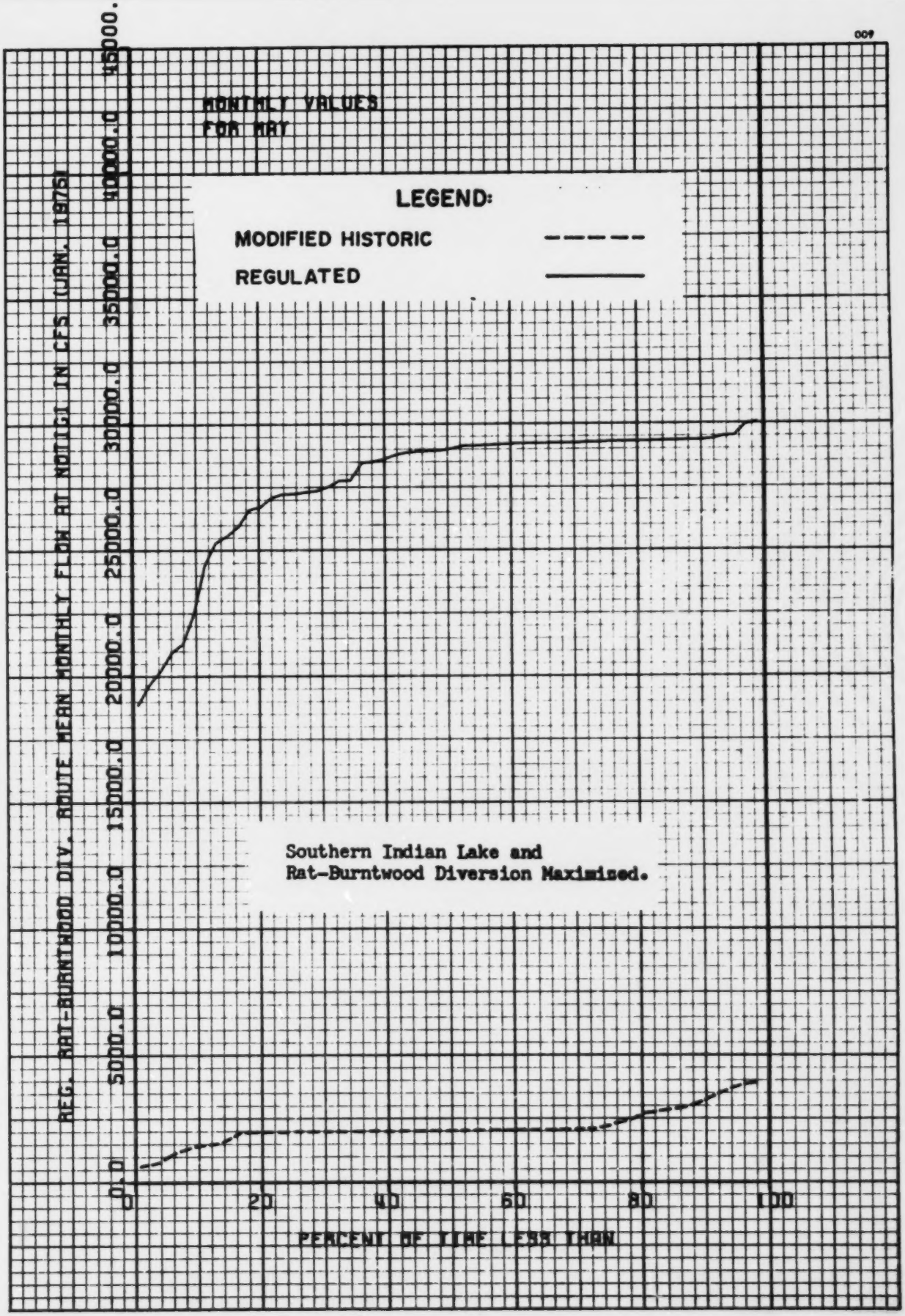
													ANNUAL
MINIMUM	17586	16945	16631	15621	18867	21462	23789	23611	22647	20166	19566	18192	15621
AVERAGE	28706	28395	27429	26846	27636	27497	28686	29611	29349	29508	29448	28795	28492
MAXIMUM	30046	30050	30047	29491	30040	30048	30050	30050	30050	30050	30050	30050	30050

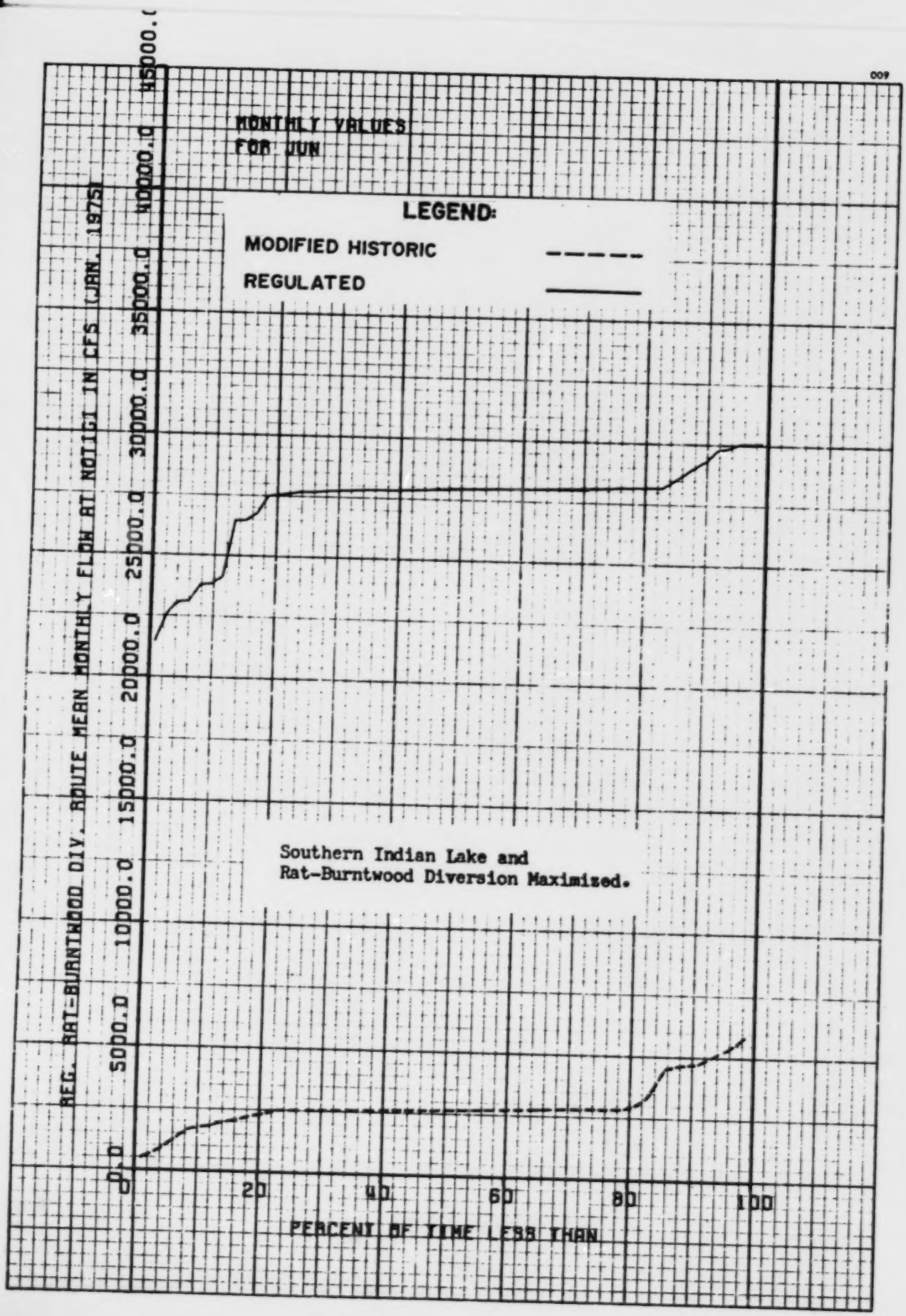

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

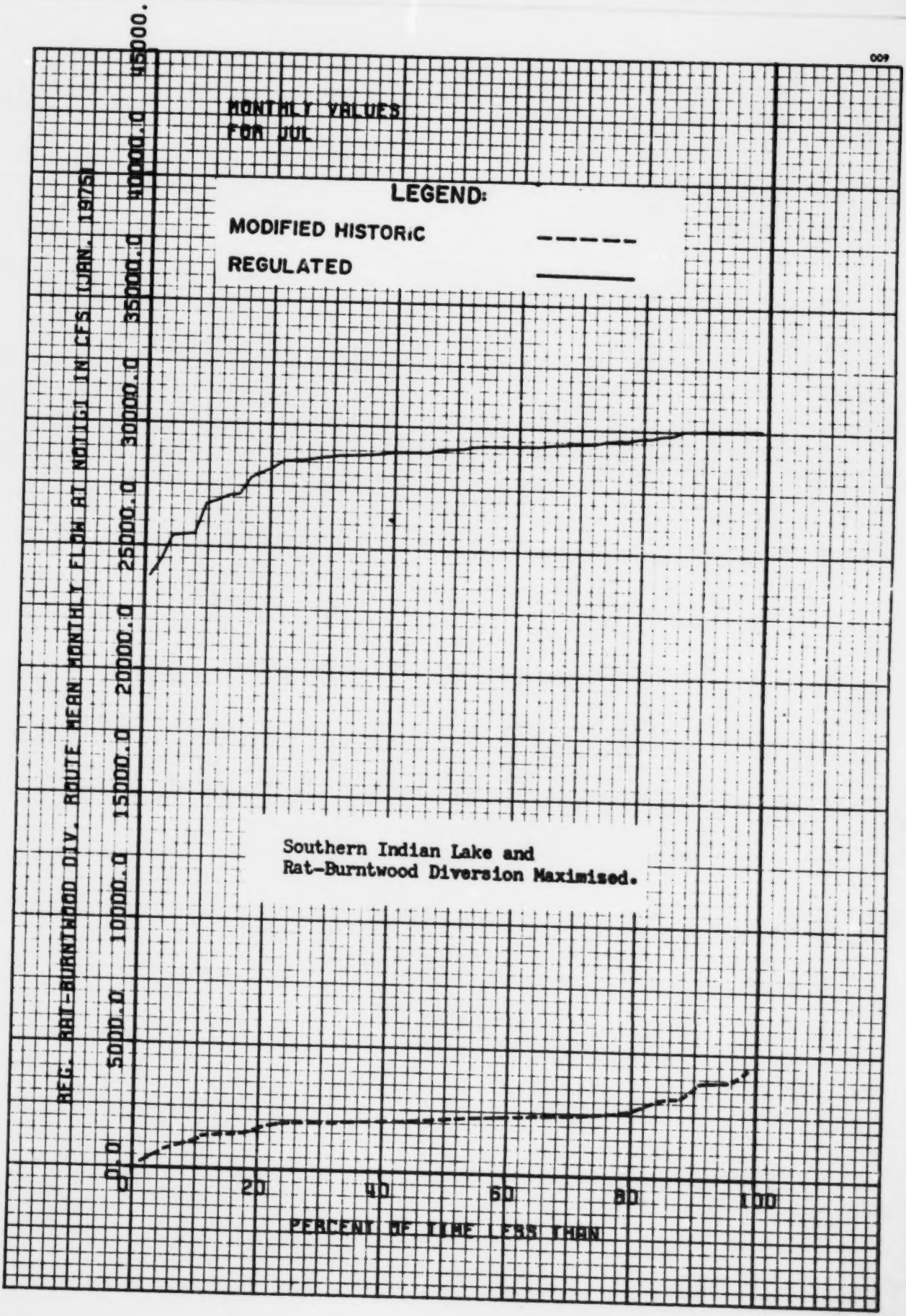

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

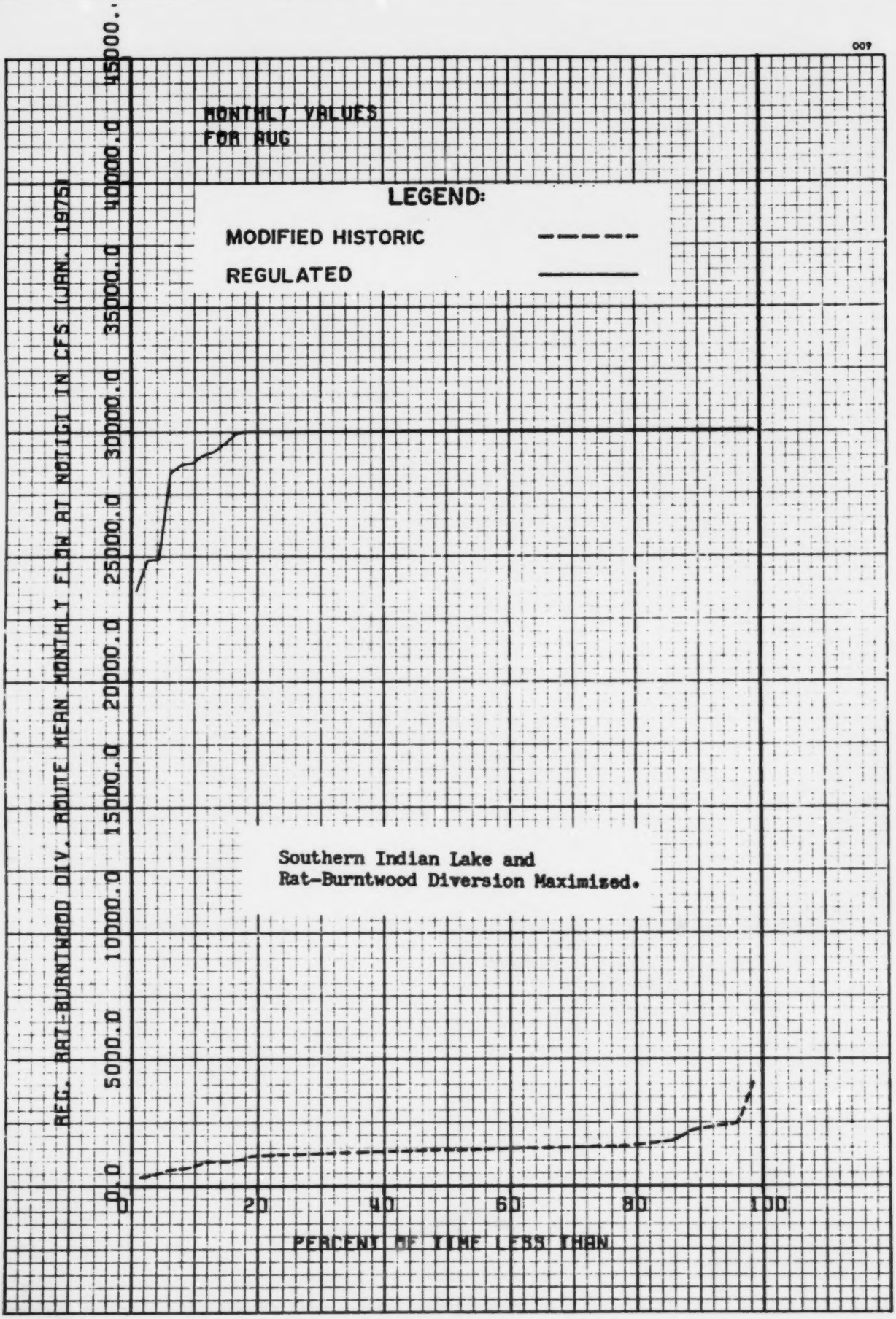

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximised.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

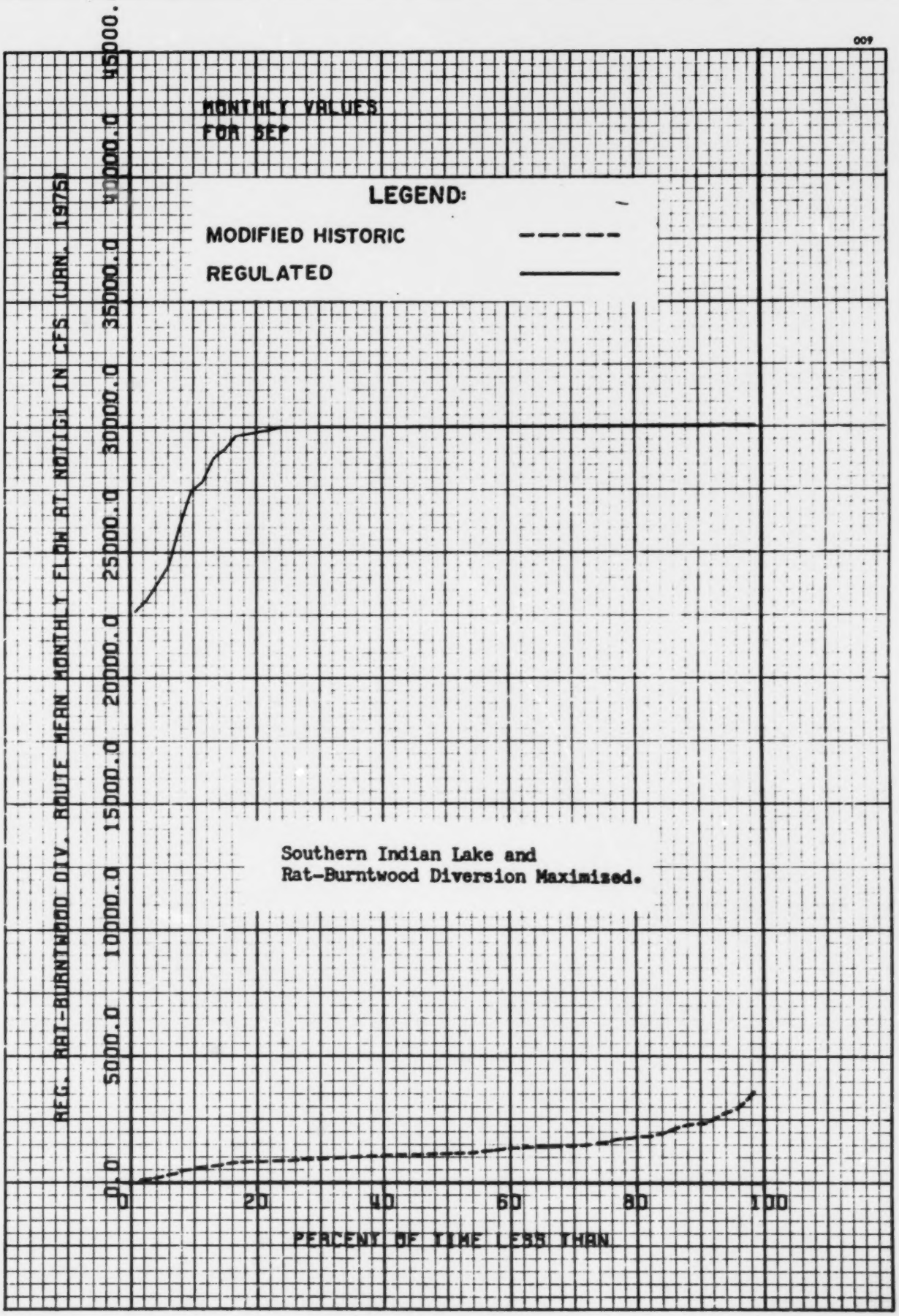

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

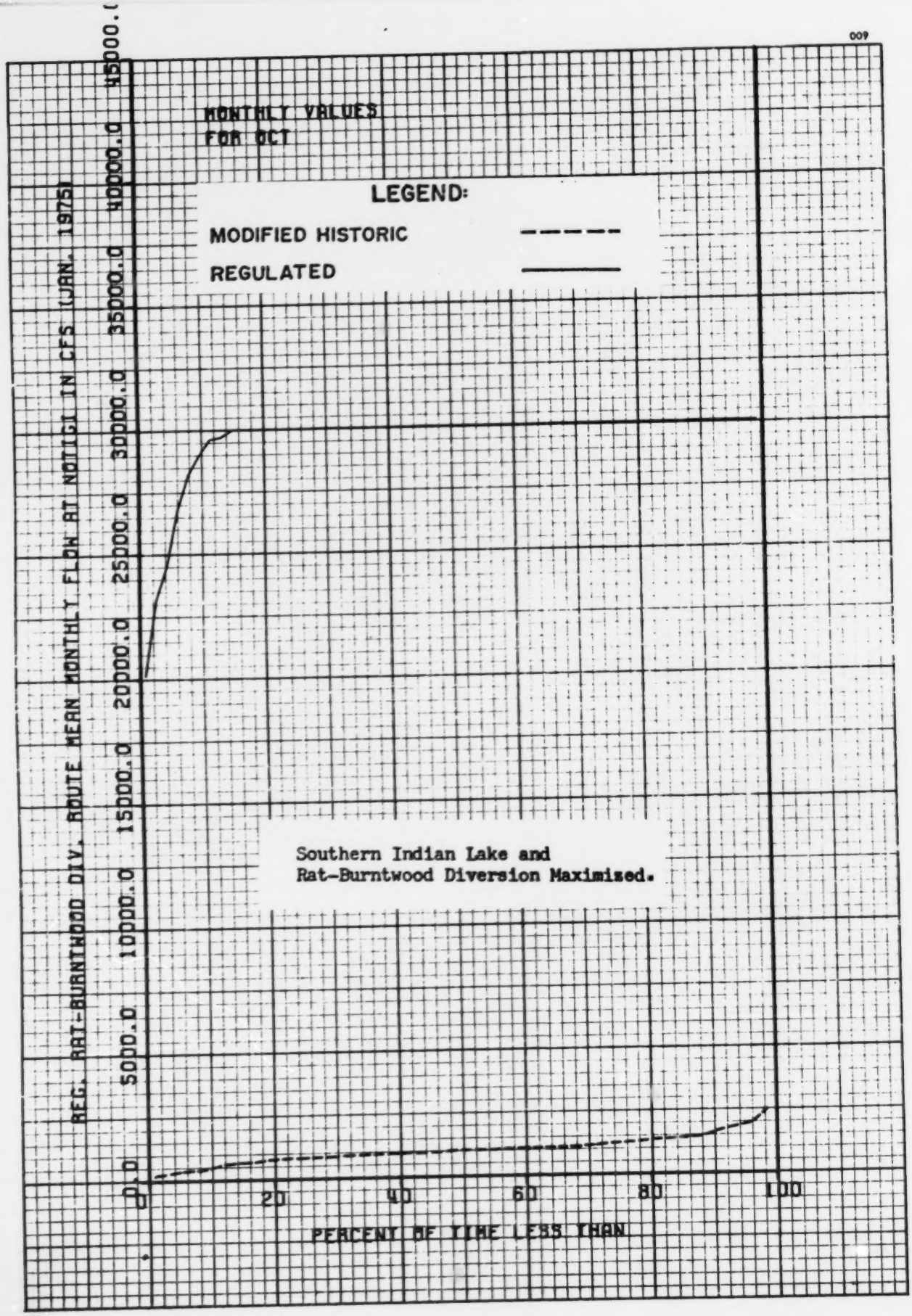

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

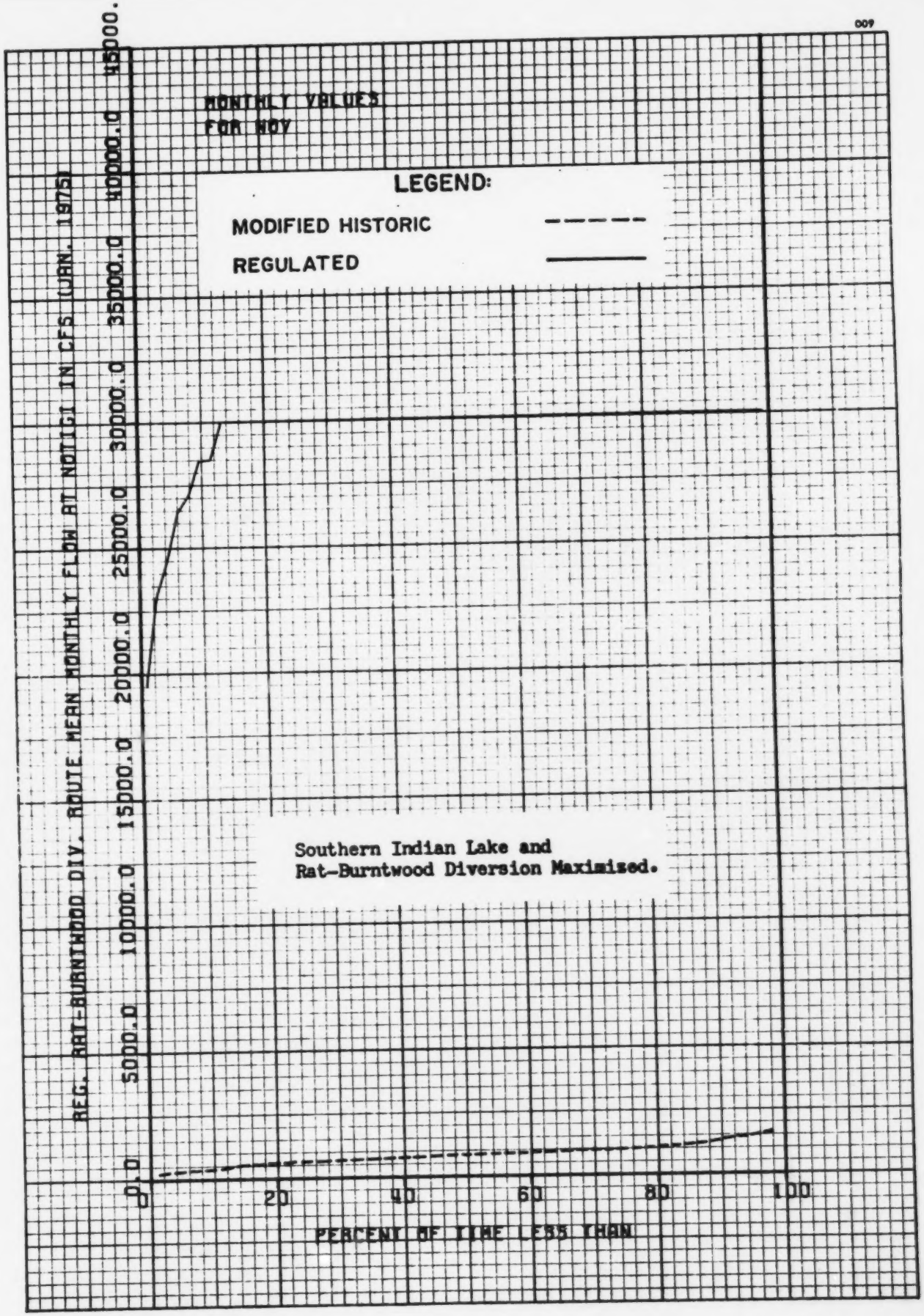

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN

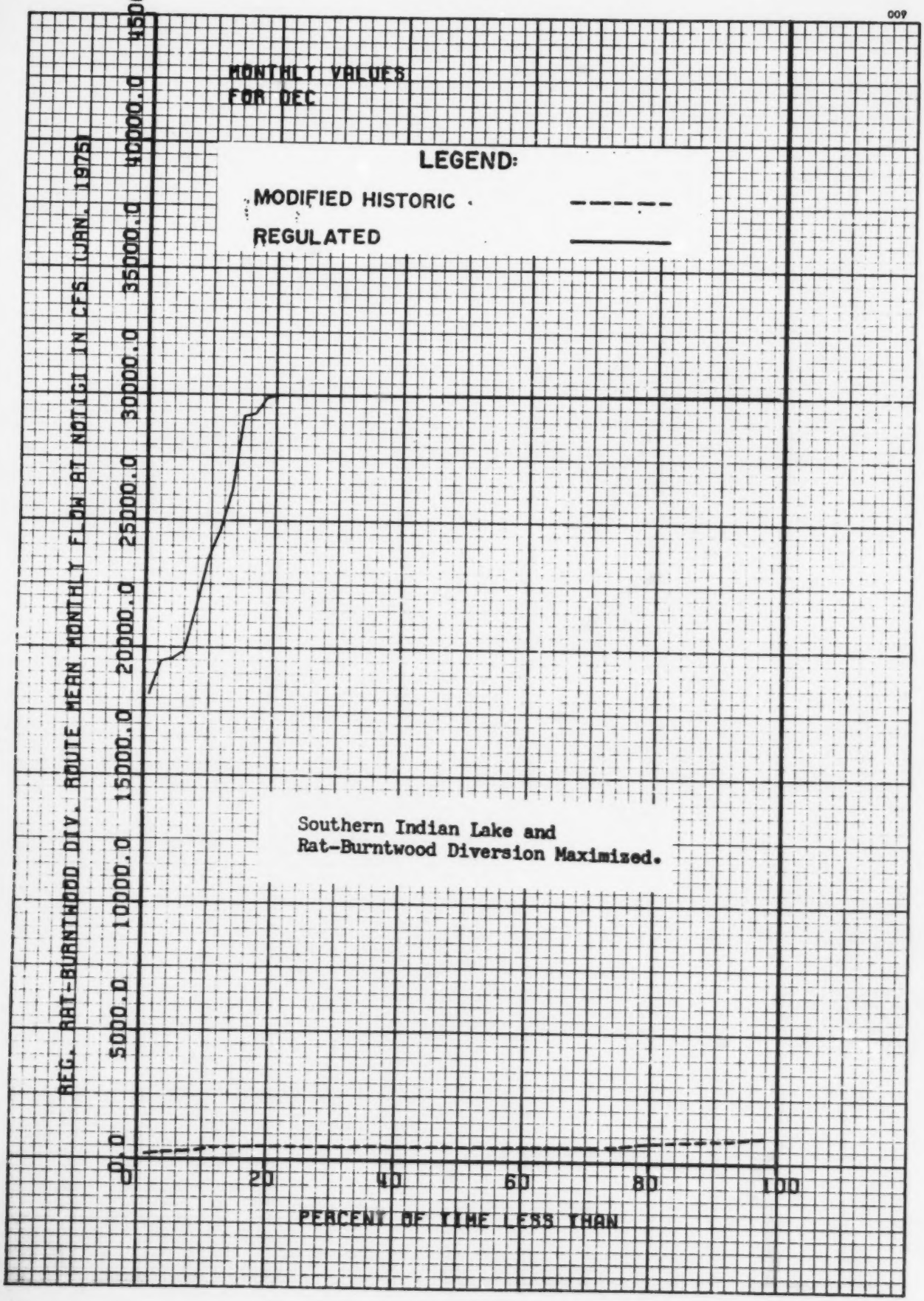

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT NOTIGI IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

WUSKWATIM POWER SITE
FLOWS

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

WUSKWATIM POWER SITE FLOWS HYDROLOGIC PERIOD 1928 - 1966

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	8	92	5	95	8	92	74	26	68	0	74	13	8	87	11	87	24	76	13	84	6	94	5	95
5-10	0	0	0	0	0	0	0	0	32	0	8	3	0	5	0	3	0	0	0	3	0	0	0	0
10-20	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

													ANNUAL
MINIMUM	293	260	242	264	1967	1578	493	920	360	482	545	425	242
AVERAGE	1080	914	800	894	5933	7715	5991	4012	3626	2801	2172	1514	3121
MAXIMUM	2202	1935	1778	2563	10733	15746	11776	11309	9654	6875	4438	2730	15746

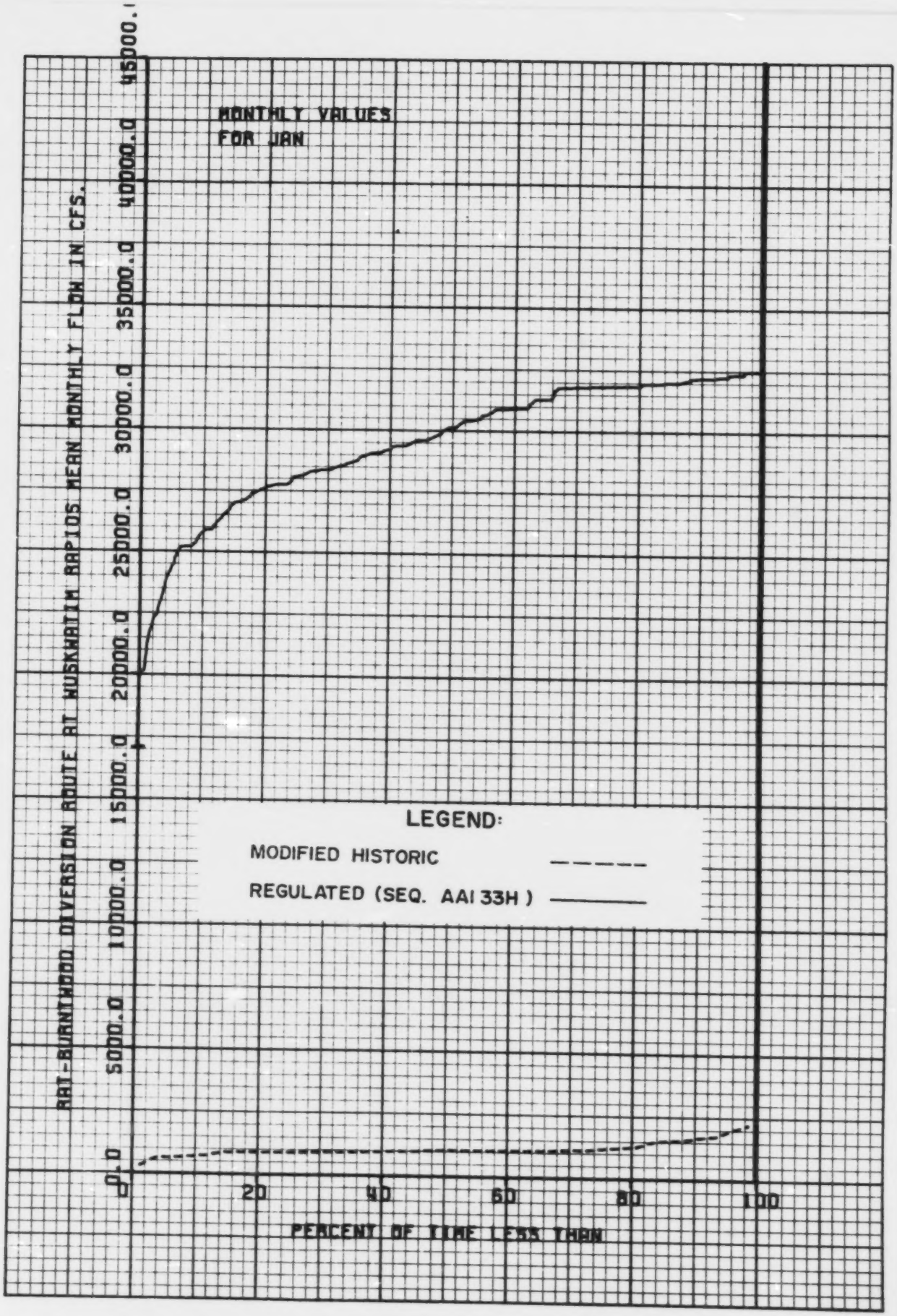
POST DIVERSION FLOWS

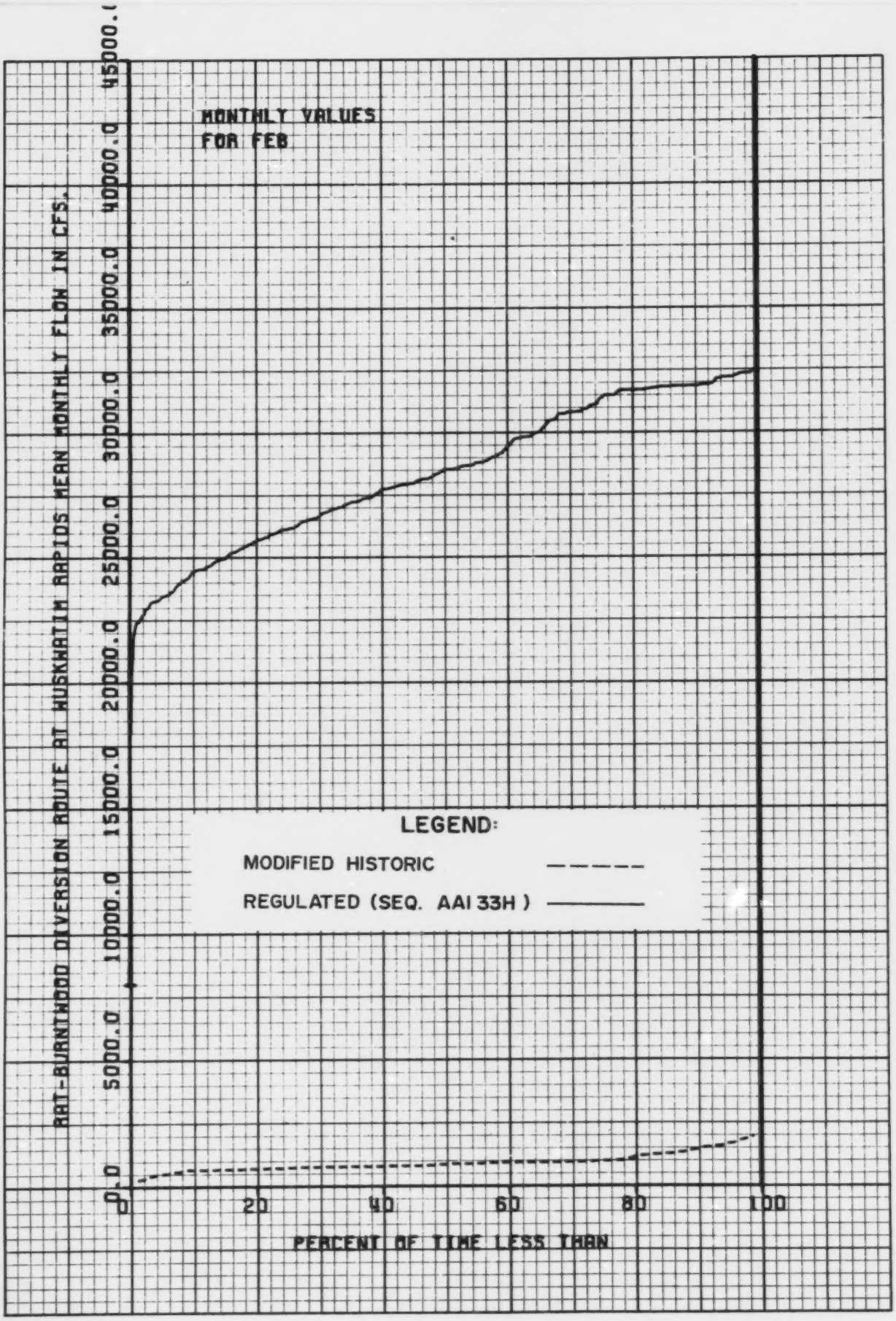
- FLUCTUATIONS IN PERCENT -

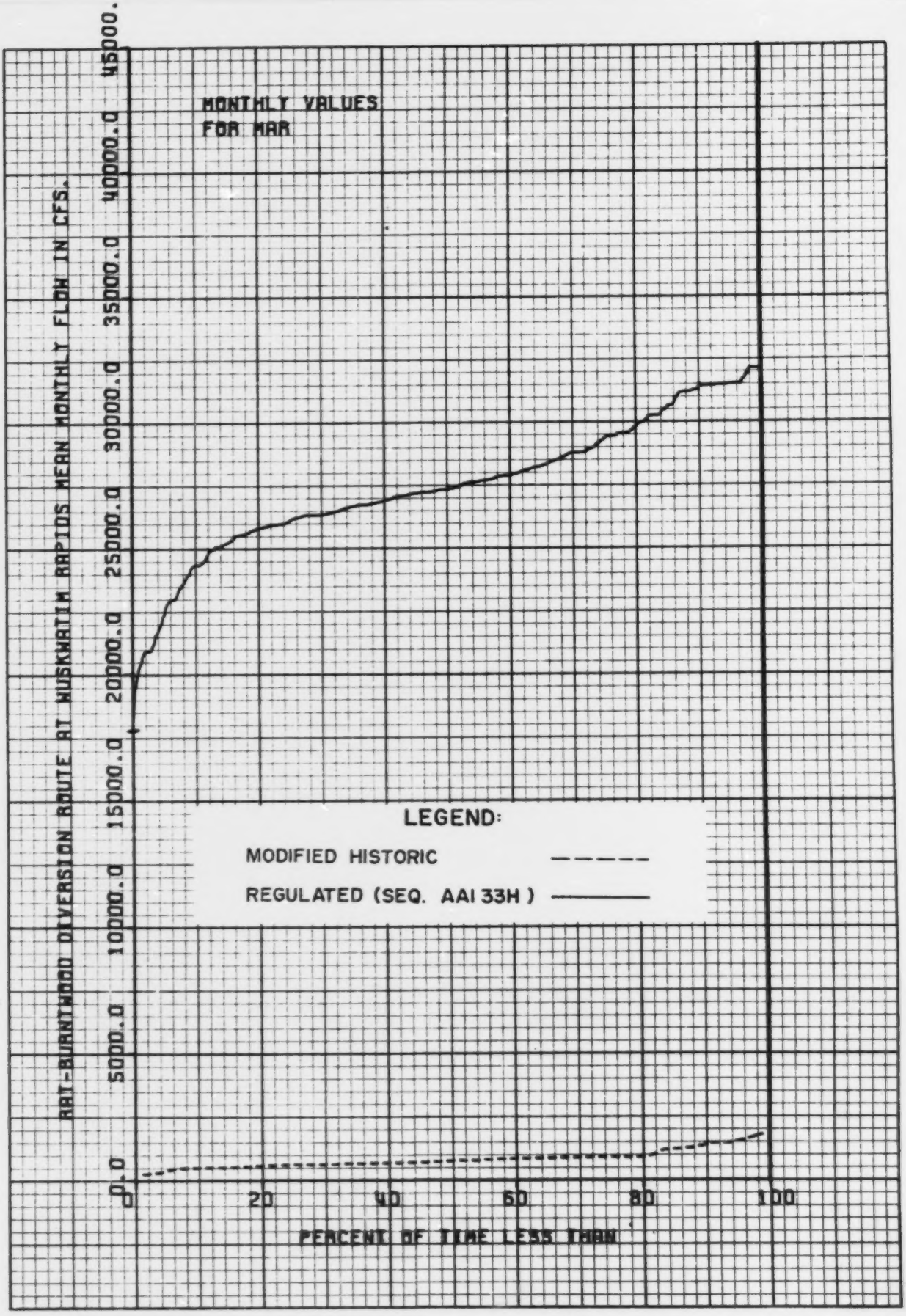
Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	16	80	17	79	26	64	36	44	38	5	84	0	100	0	87	13	54	44	35	57	19	77	8	81
5-10	1	2	1	2	0	8	6	9	38	2	11	0	0	0	0	0	0	2	0	8	1	3	0	10
10-20	0	0	0	1	1	1	1	4	15	1	5	0	0	0	0	0	0	0	0	0	0	0	0	1
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

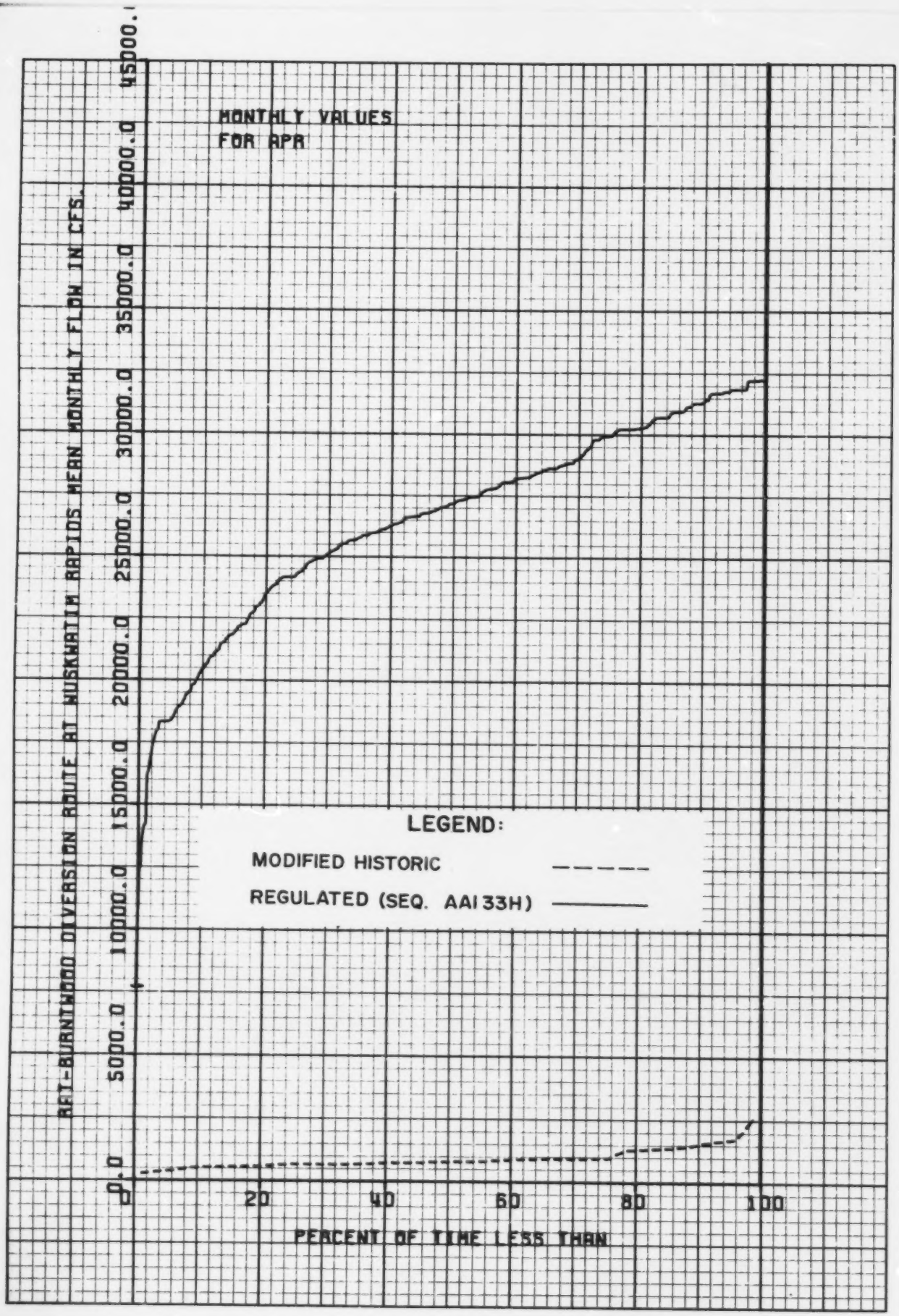
- FLOWS IN CFS

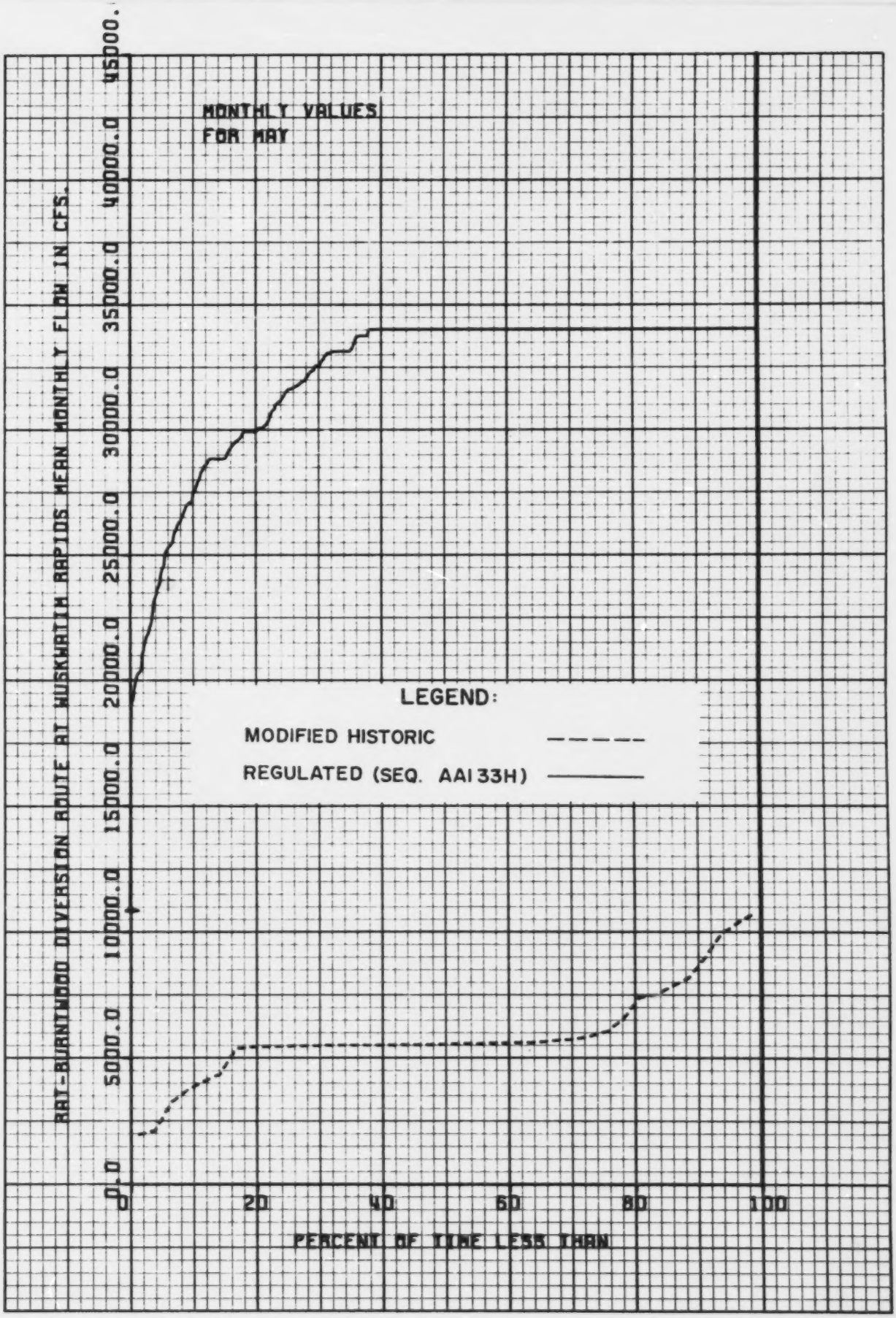
													ANNUAL
MINIMUM	17042	7990	17767	7718	10841	31041	34000	32736	24683	25060	19876	17781	7718
AVERAGE	29457	28295	27429	26519	32120	33991	34000	33937	33384	32562	32056	30286	31170
MAXIMUM	32461	32405	32119	32258	34000	34000	34000	34000	34000	34000	34000	33145	34000

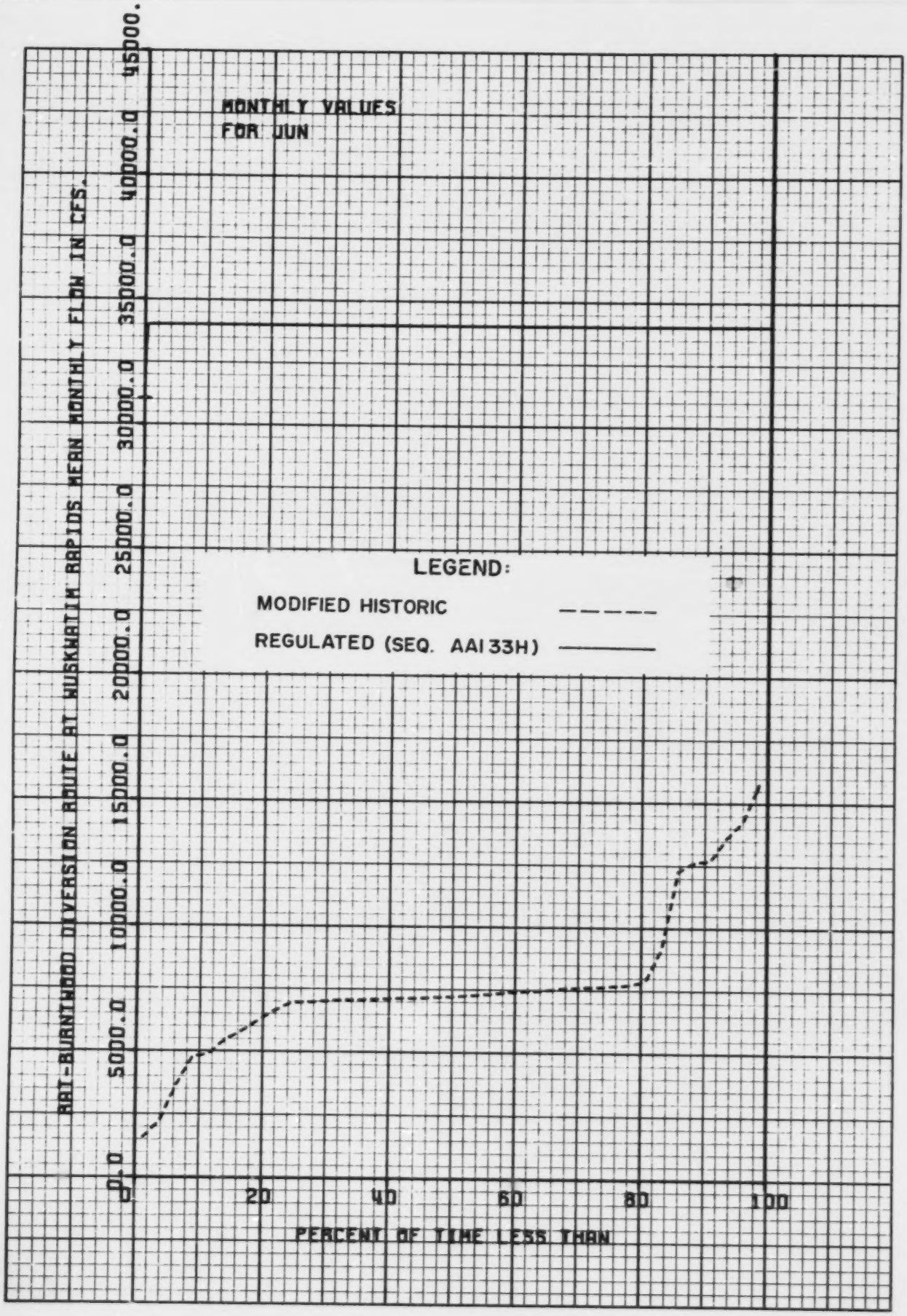

MONTHLY VALUES
FOR JAN
ABITIBI-BURNTWOOD DIVERSION ROUTE AT WUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)

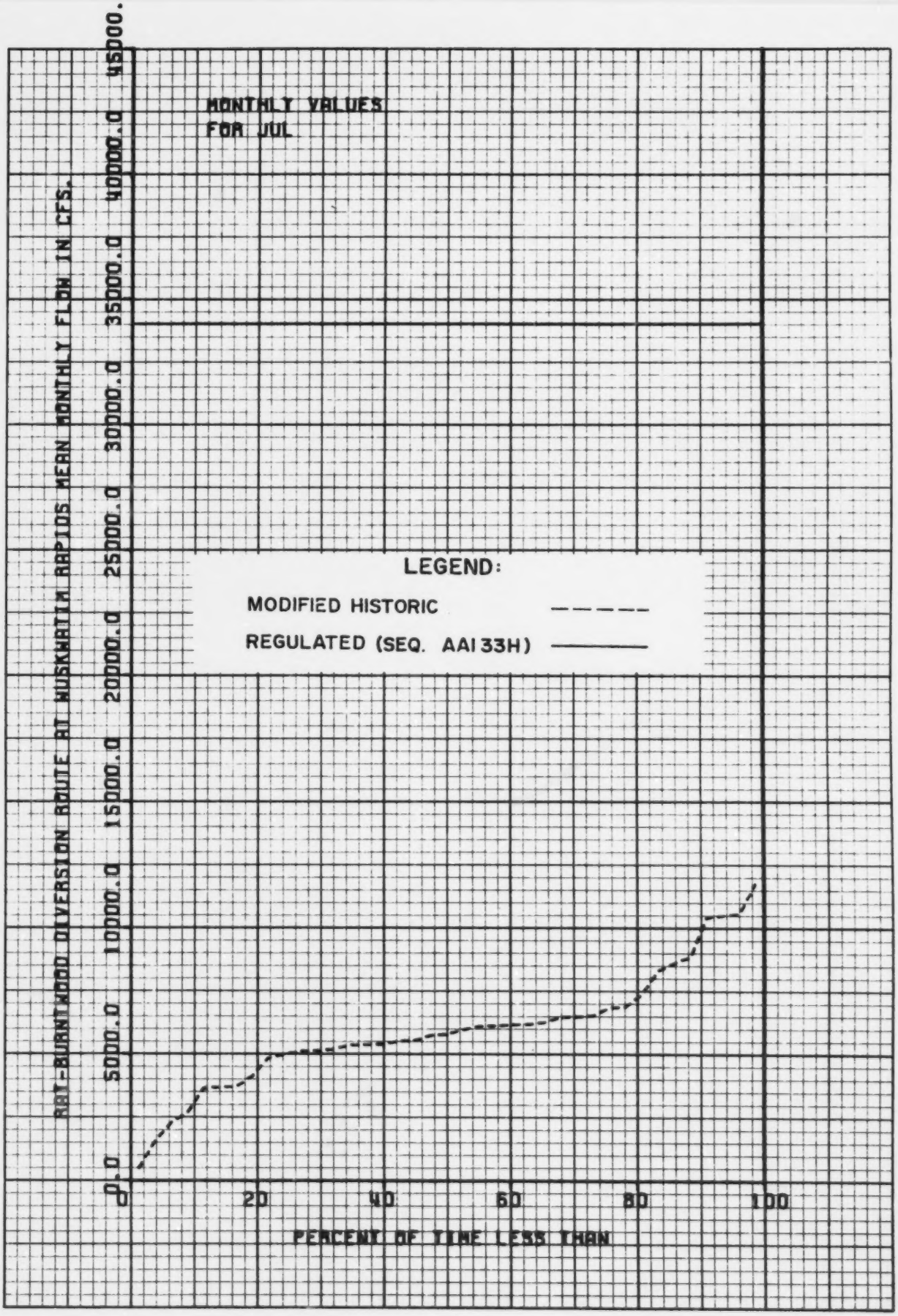

MONTHLY VALUES
FOR FEB
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.0
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

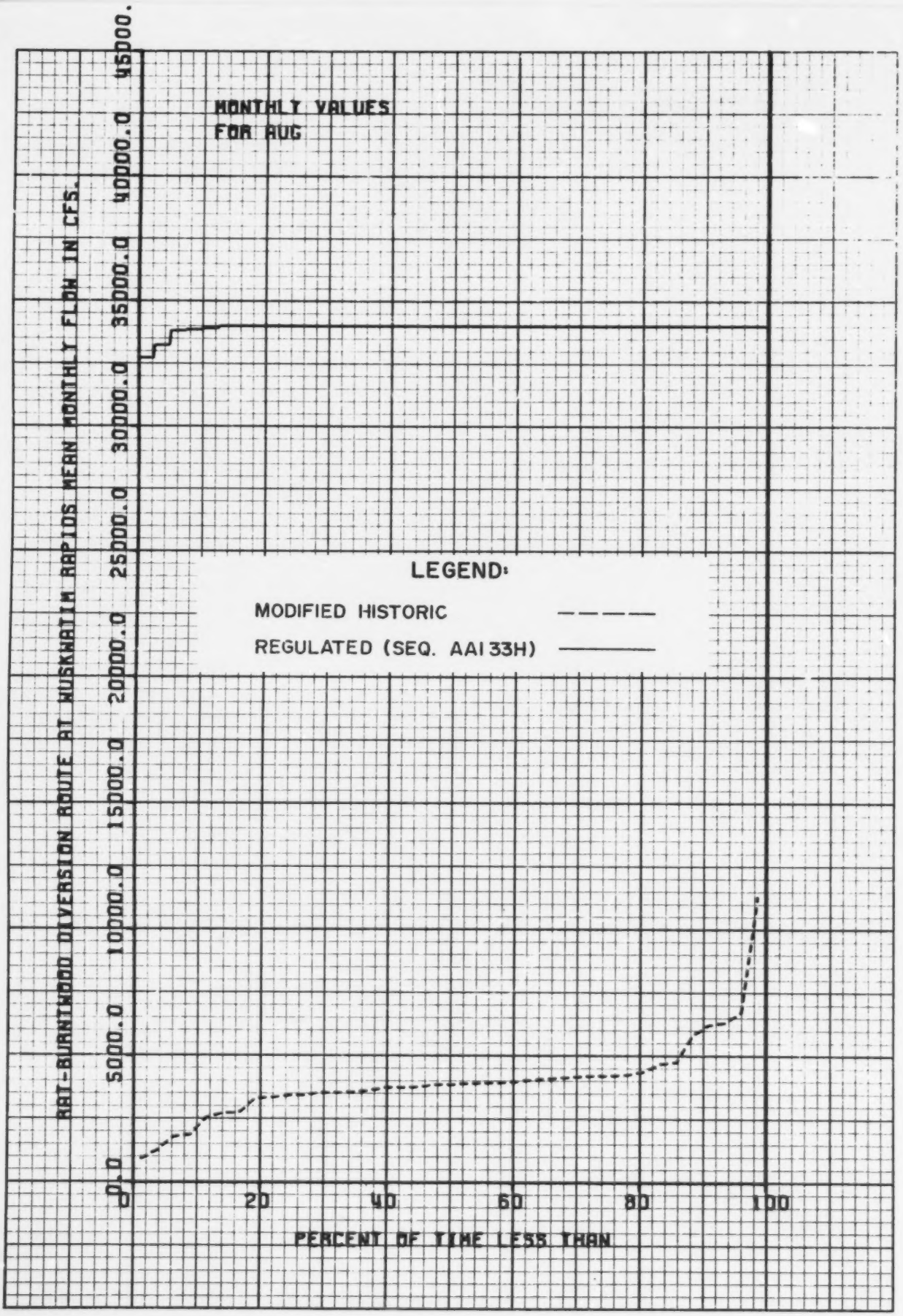

MONTHLY VALUES
FOR MAR
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKRATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)

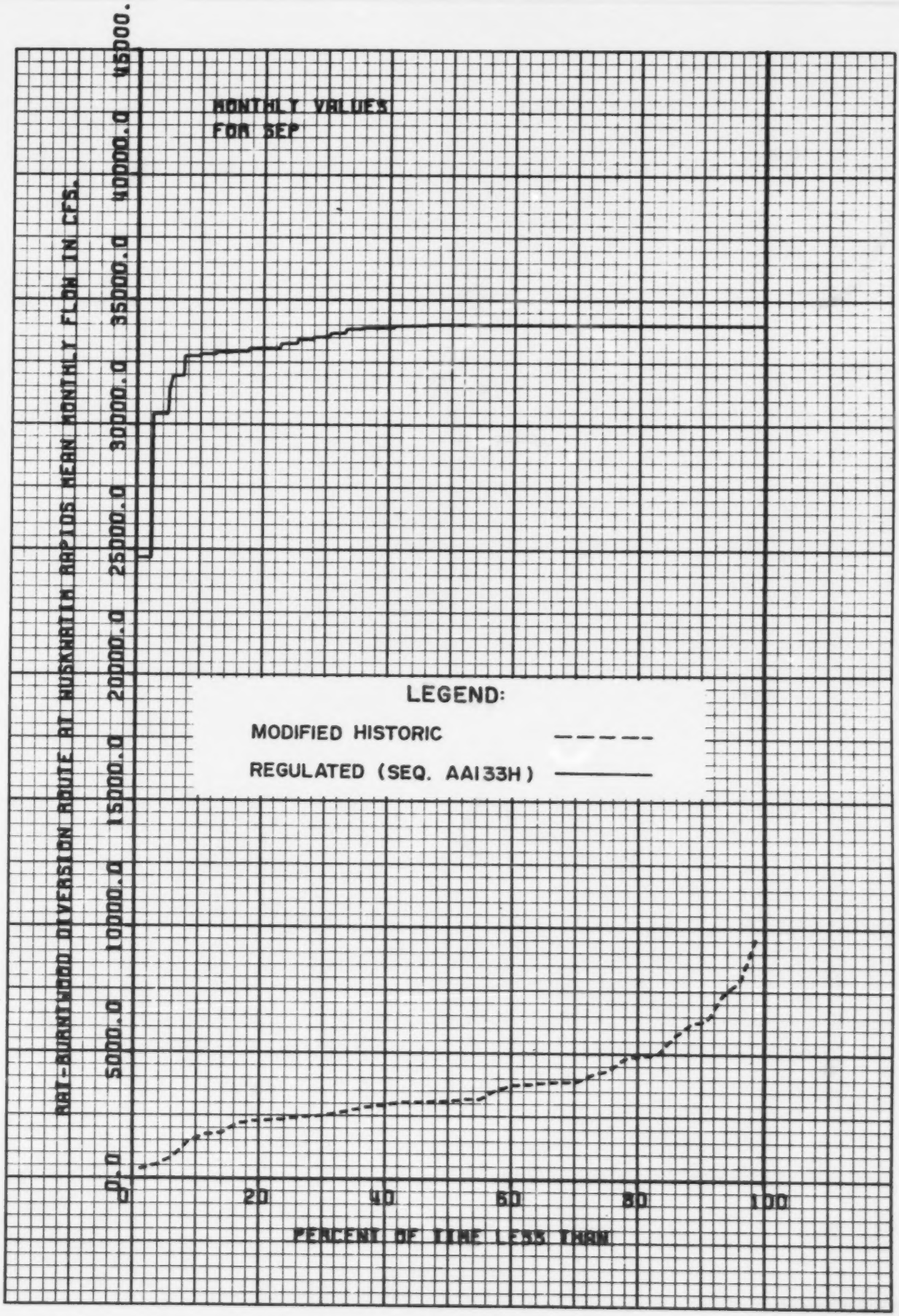

MONTHLY VALUES
FOR APR
BET-BURNTWOOD DIVERSION ROUTE AT MUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)

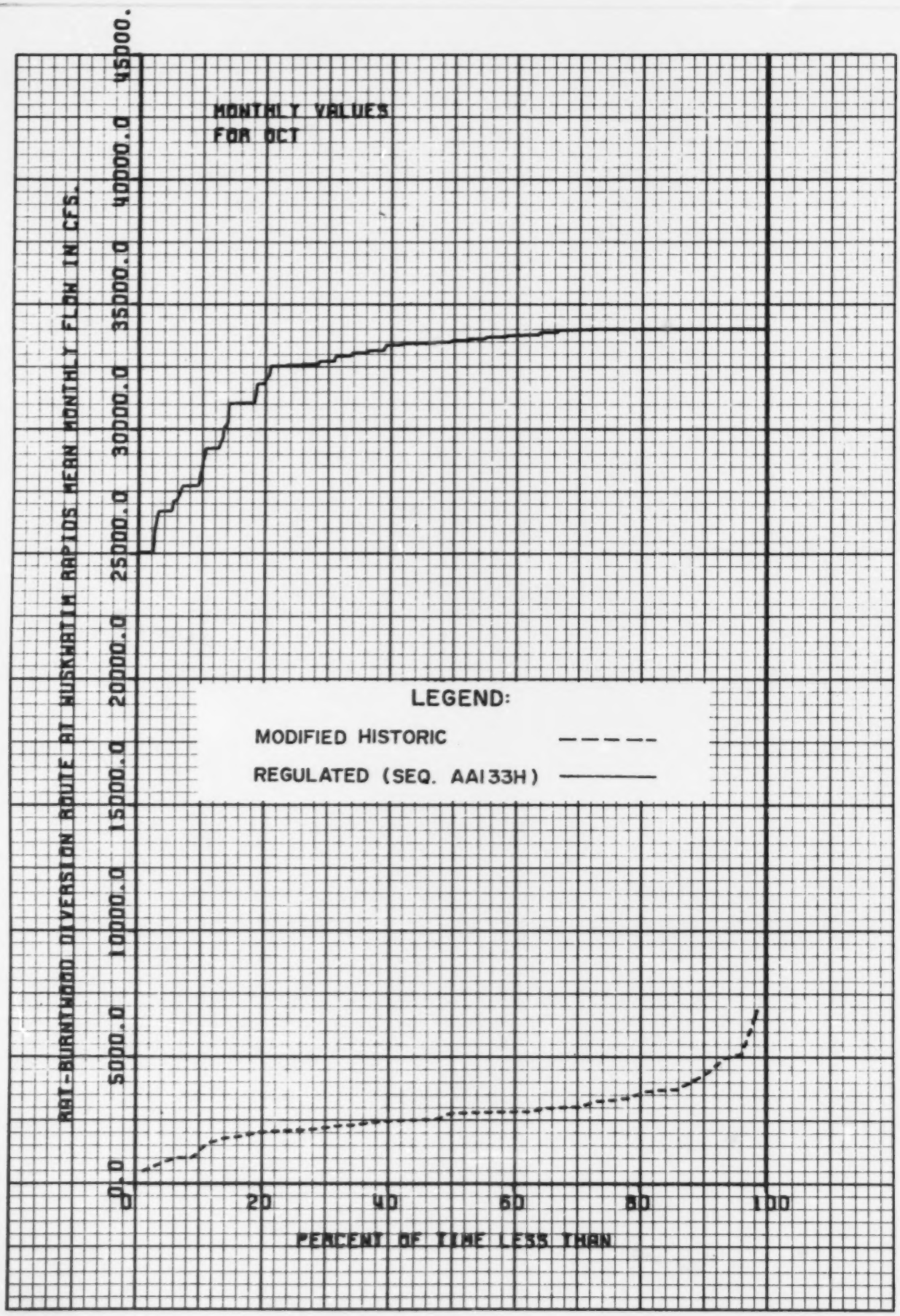

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKRATH RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

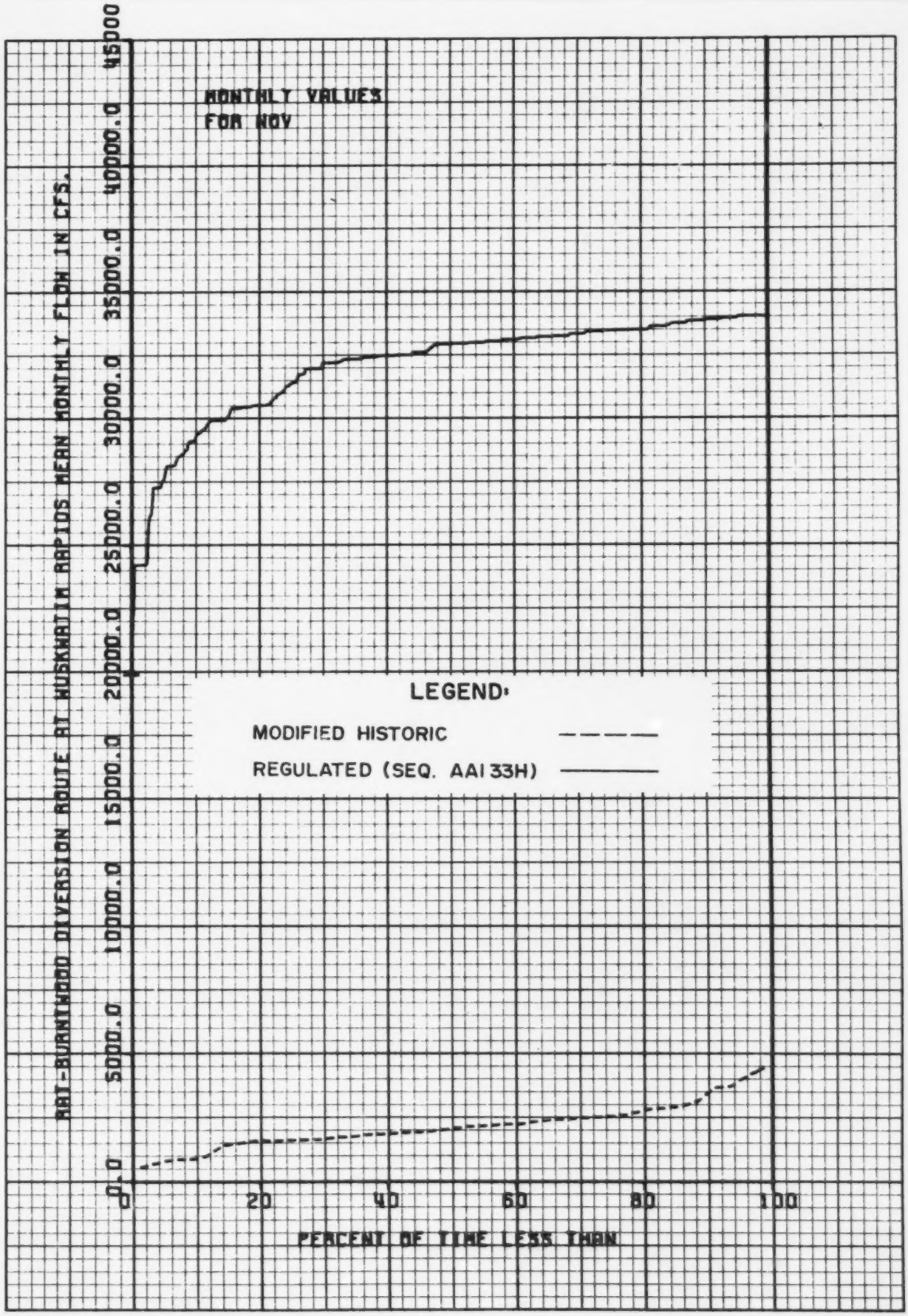

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIN RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

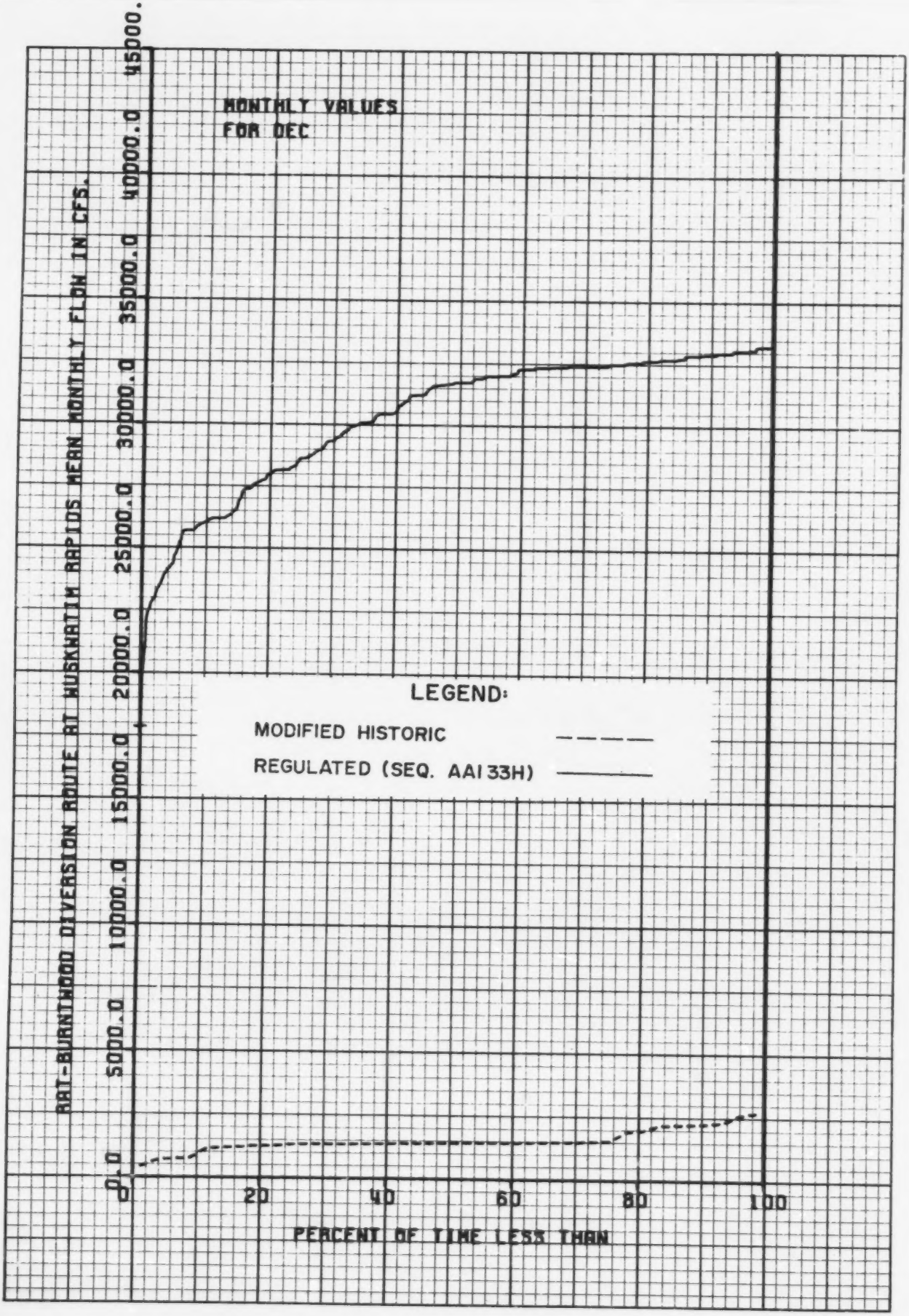

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
RBT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIN RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
RAT-BURNTWOOD DIVERSION ROUTE AT HUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
ABT-BURNTWOOD DIVERSION ROUTE AT HUSKWATIN RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
RAT-BURNTWOOD DIVERSION ROUTE AT MUSKWATIM RAPIDS MEAN MONTHLY FLOW IN CFS.
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

WISKWATIM POWER SITE FLOWS HYDROLOGIC PERIOD 1912 - 1967

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	8	92	5	95	8	92	74	26	68	0	74	13	8	87	11	86	24	76	13	84	6	94	5	95
5-10	0	0	0	0	0	0	0	0	32	0	8	3	0	5	0	3	0	0	0	3	0	0	0	0
10-20	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	293	260	242	264	1967	1578	493	920	360	482	545	425	242
AVERAGE	1077	921	814	893	5760	7606	5911	3975	3489	2710	2076	1488	7606
MAXIMUM	2202	1935	1778	2563	10733	15746	11776	11309	9654	6875	4438	2730	15746

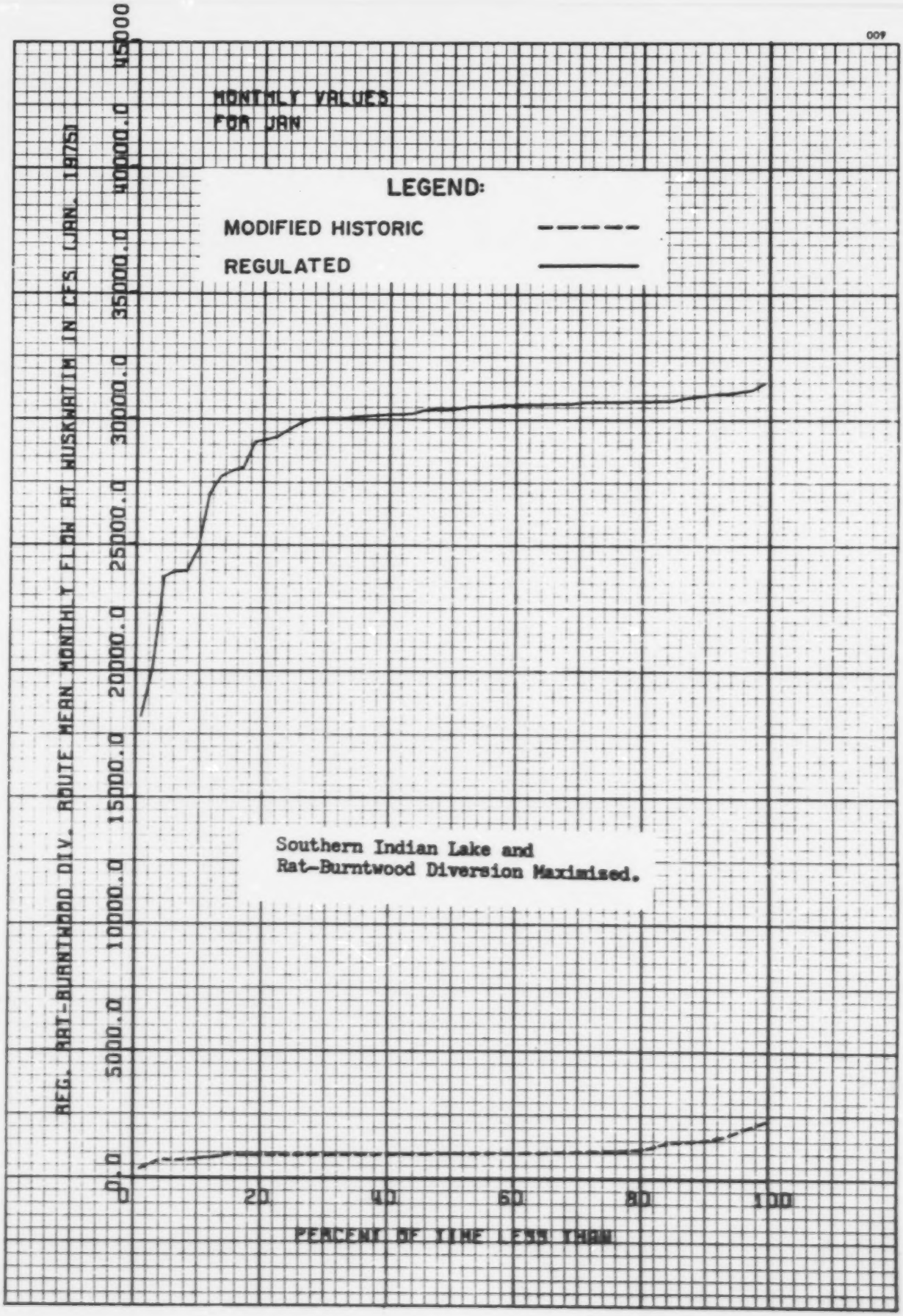
POST DIVERSION FLOWS

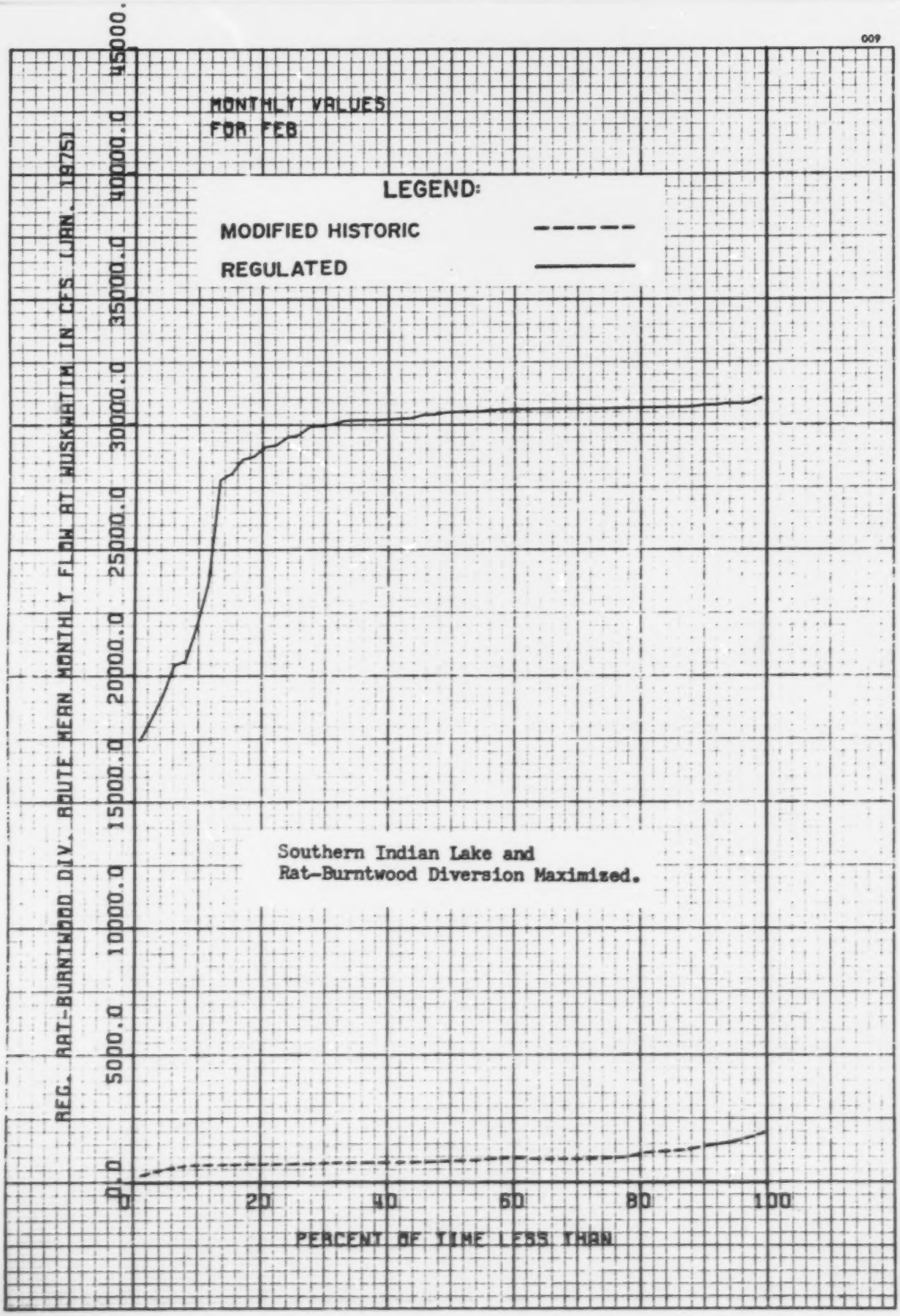
- FLUCTUATIONS IN PERCENT -

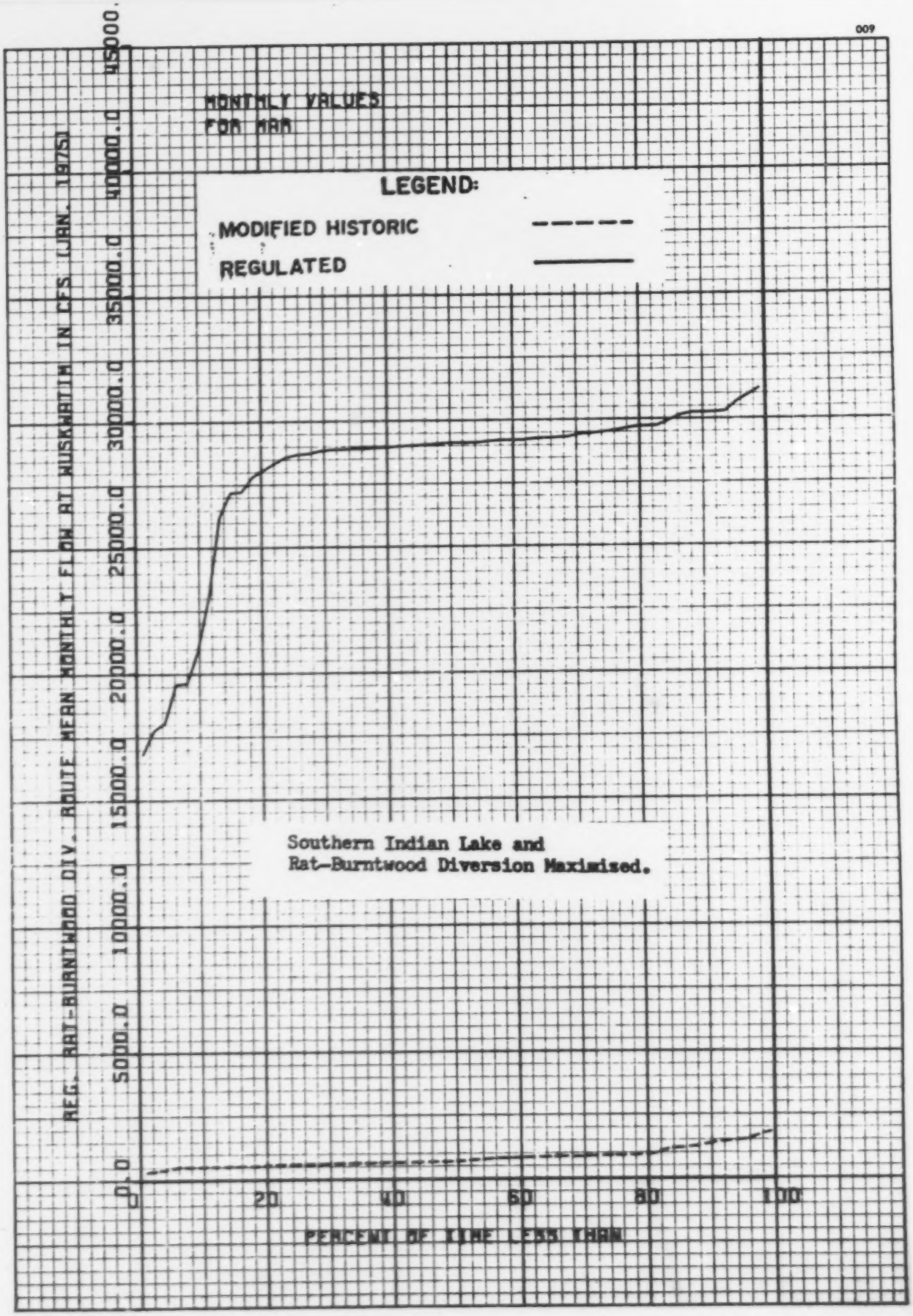
Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	11	85	39	59	16	84	16	84	85	2	36	55	82	18	29	71	18	78	16	82	9	91	7	82
5-10	4	0	0	2	0	0	0	0	13	0	9	0	0	0	0	0	0	4	0	2	0	0	0	11
10-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

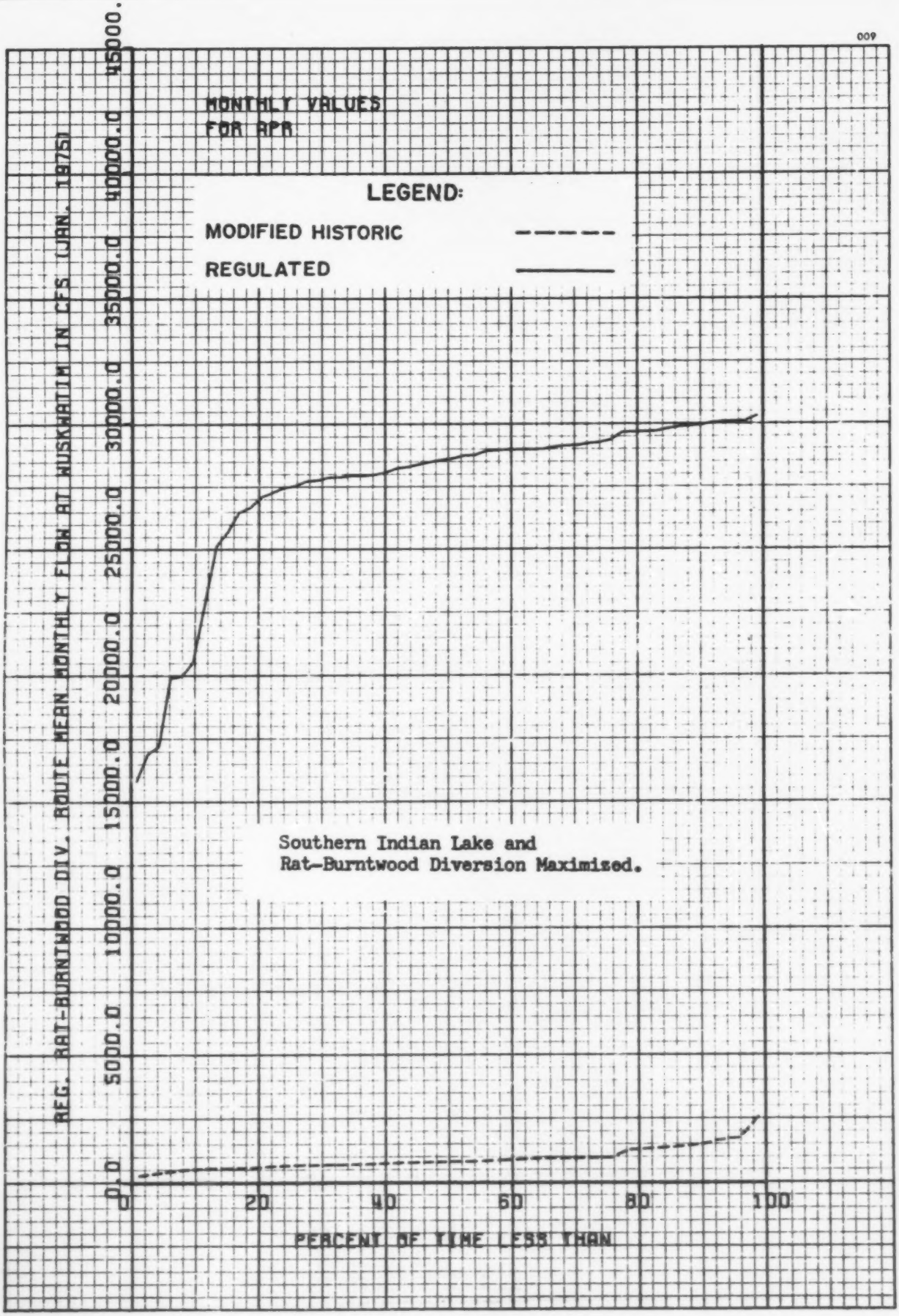
- FLOWS IN CFS -

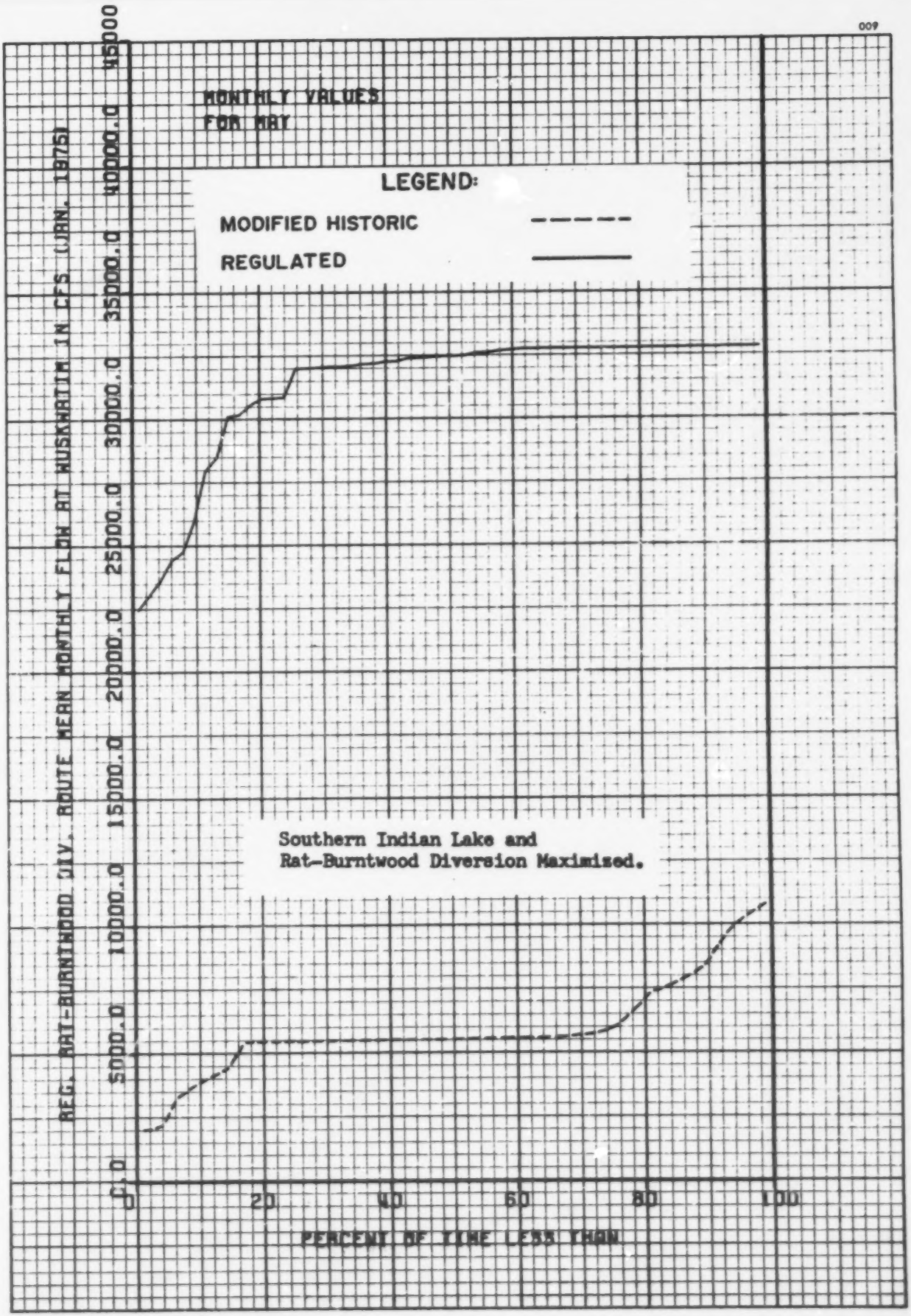
	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	18182	17436	16823	15841	22458	27913	28100	26605	25002	22423	21509	19119	15841
AVERAGE	29383	28974	27941	27407	31257	32279	32402	32110	31543	31187	30727	29712	30410
MAXIMUM	31412	31033	31167	30286	32783	32851	32869	32890	32881	32850	32825	31672	32890

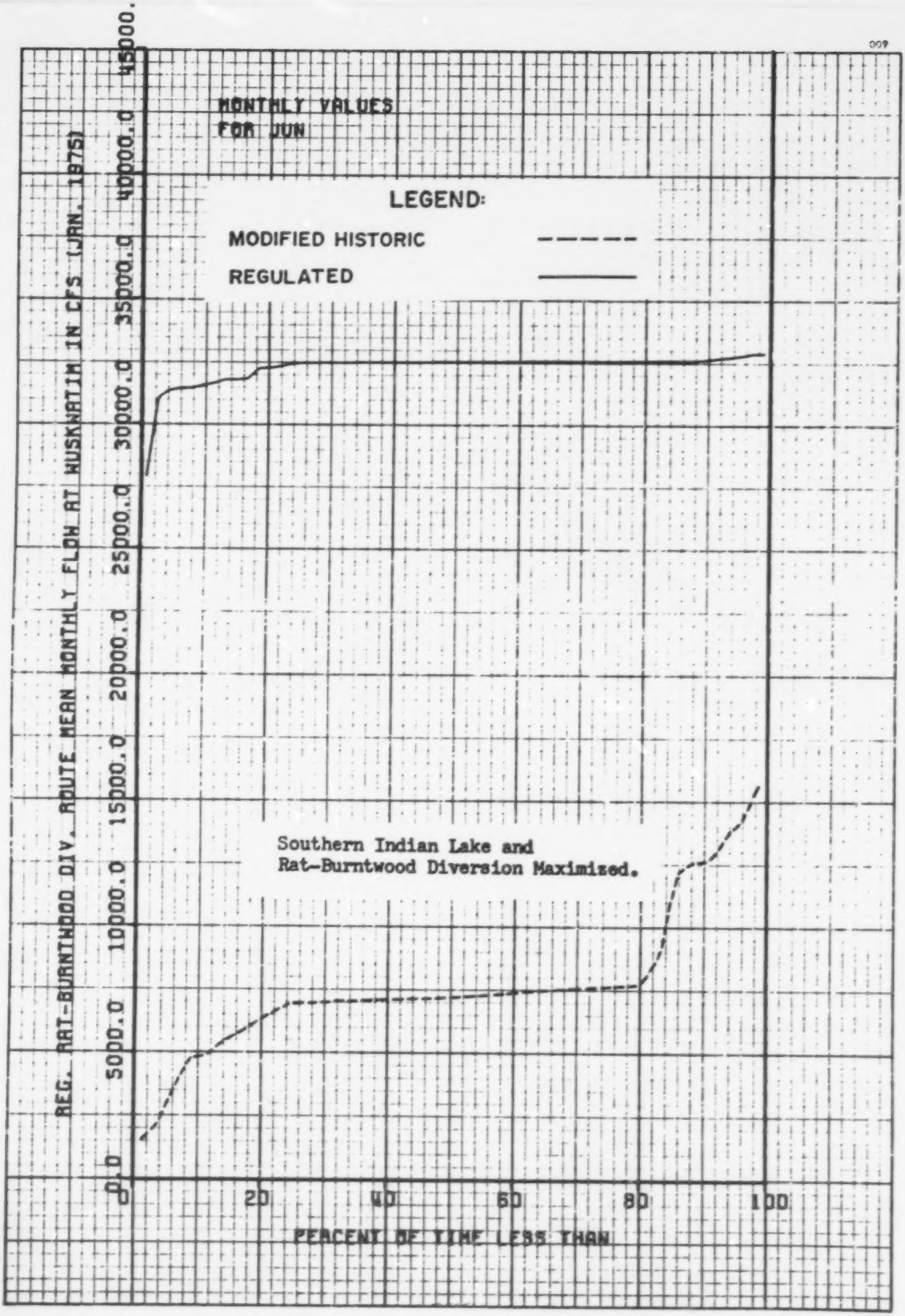

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKWATIM IN CFS (JAN. 1875)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000
20
40
60
80
100
PERCENT OF TIME LESS THAN

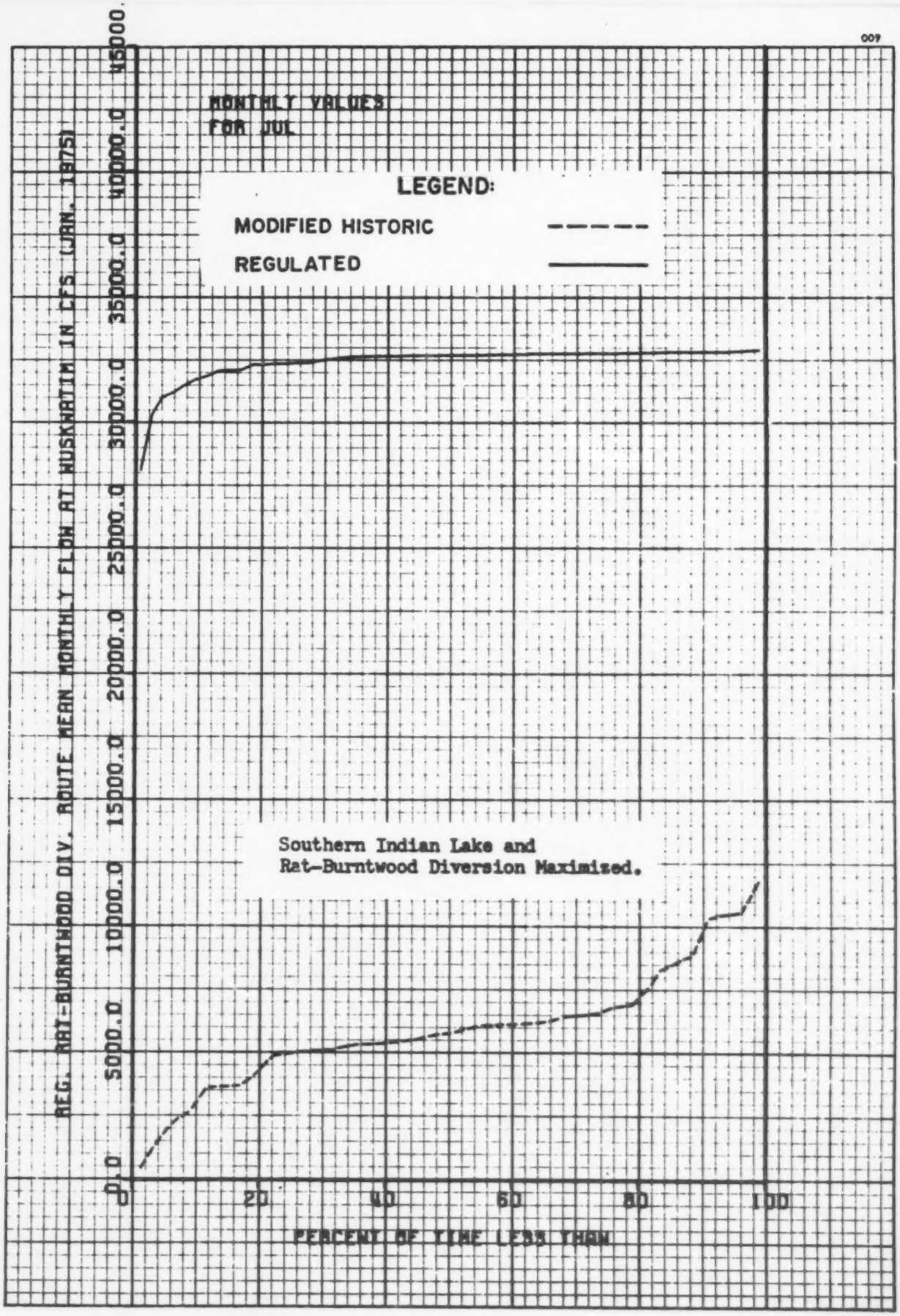

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKWATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

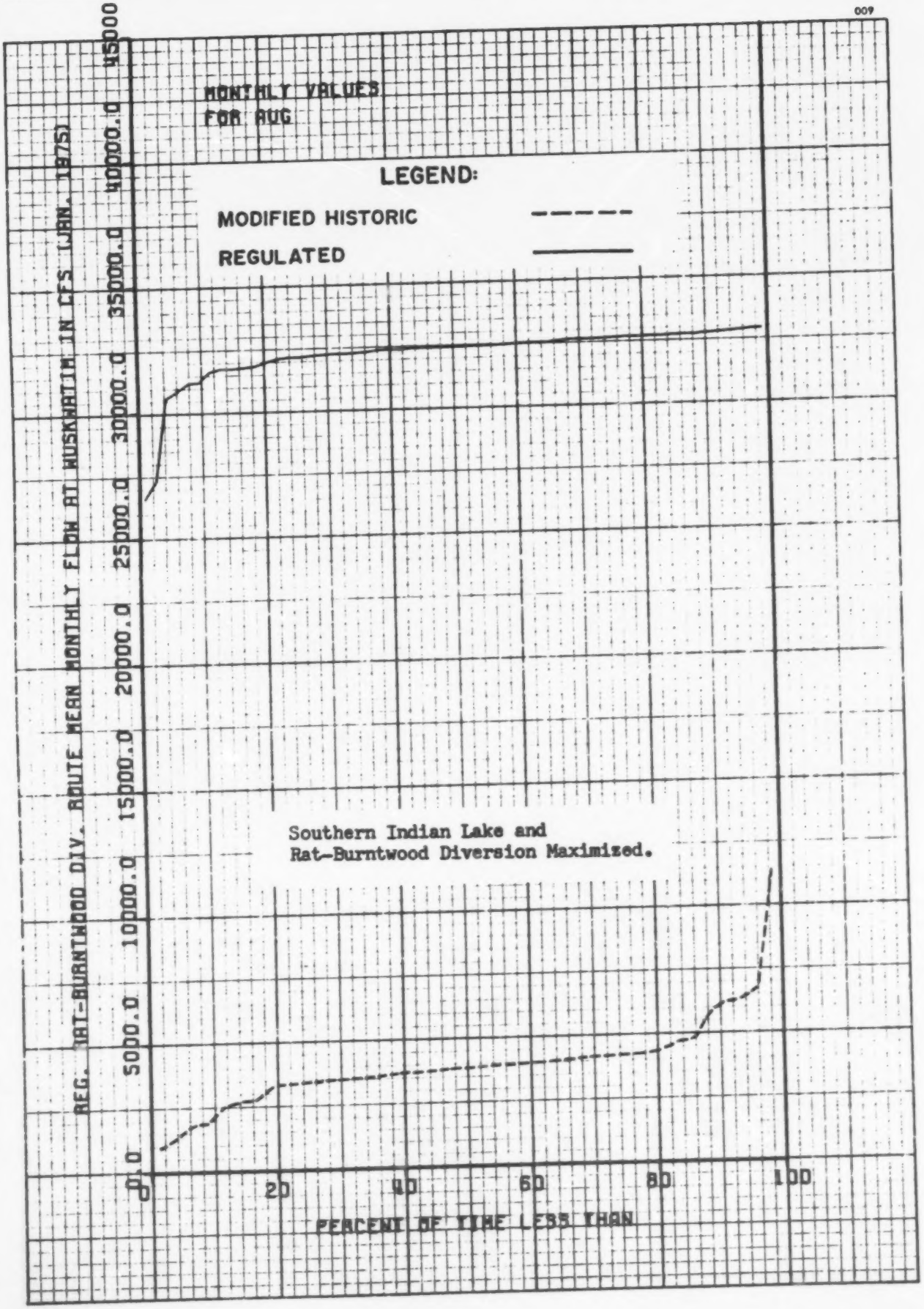

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKWATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

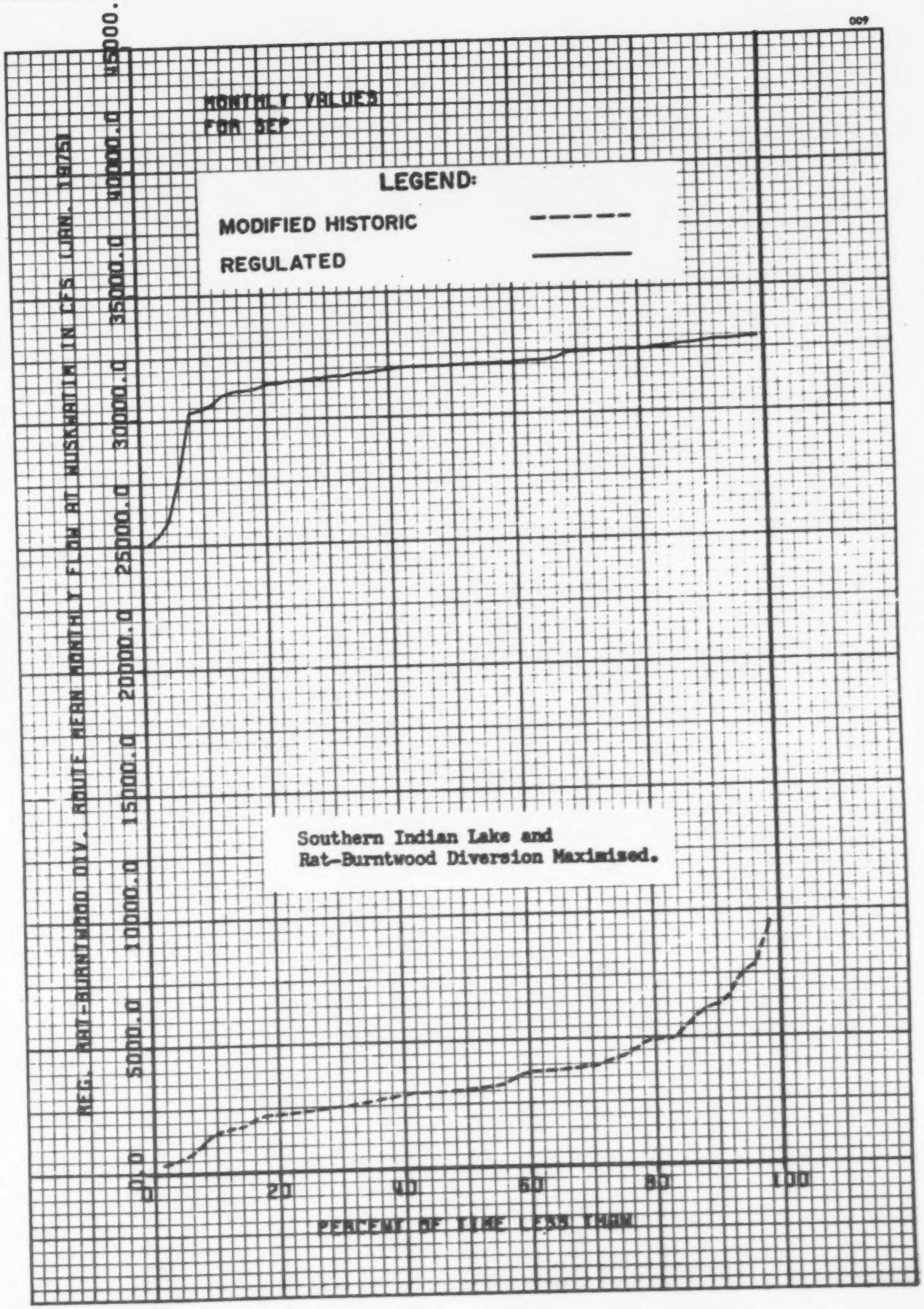

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

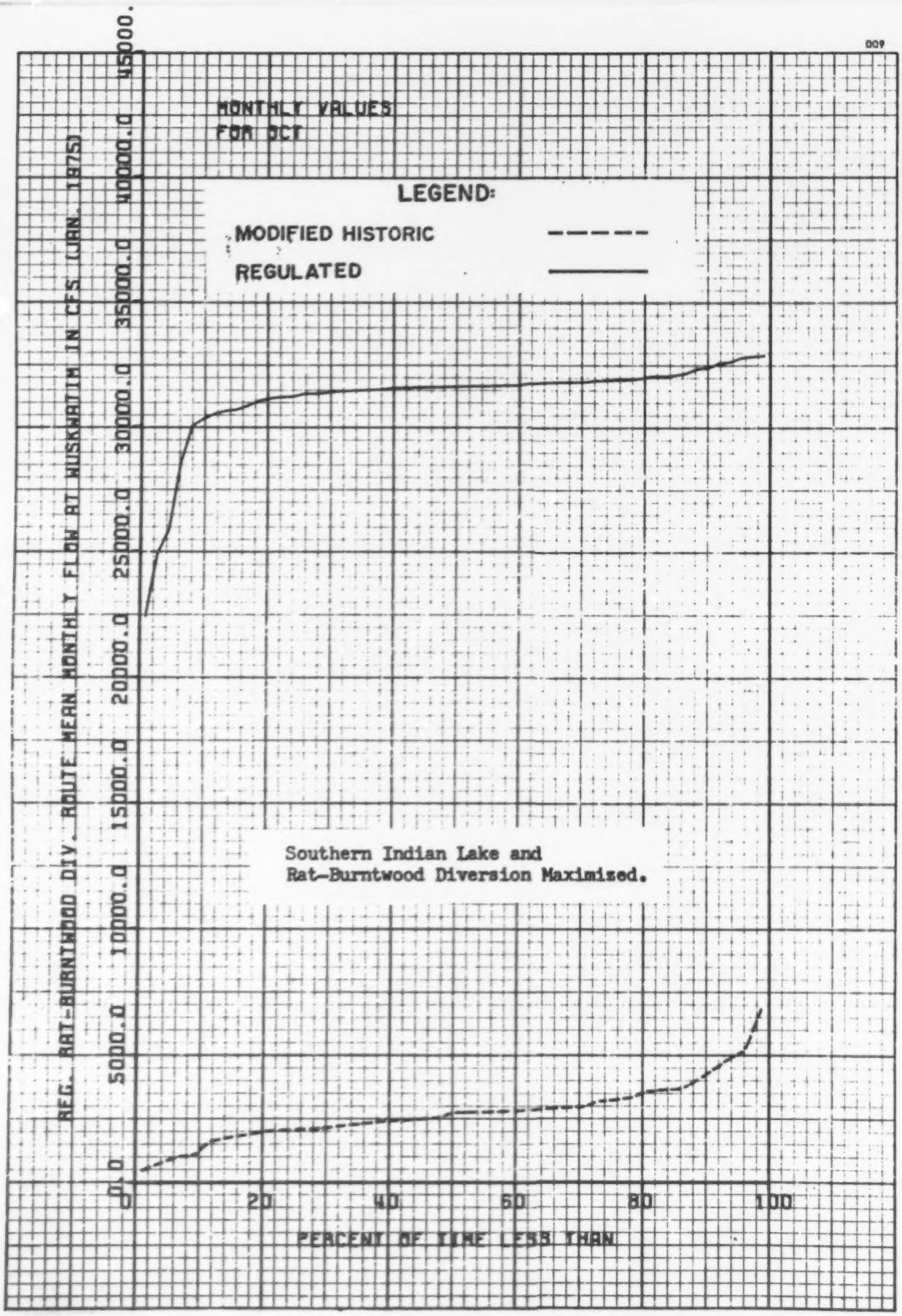

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

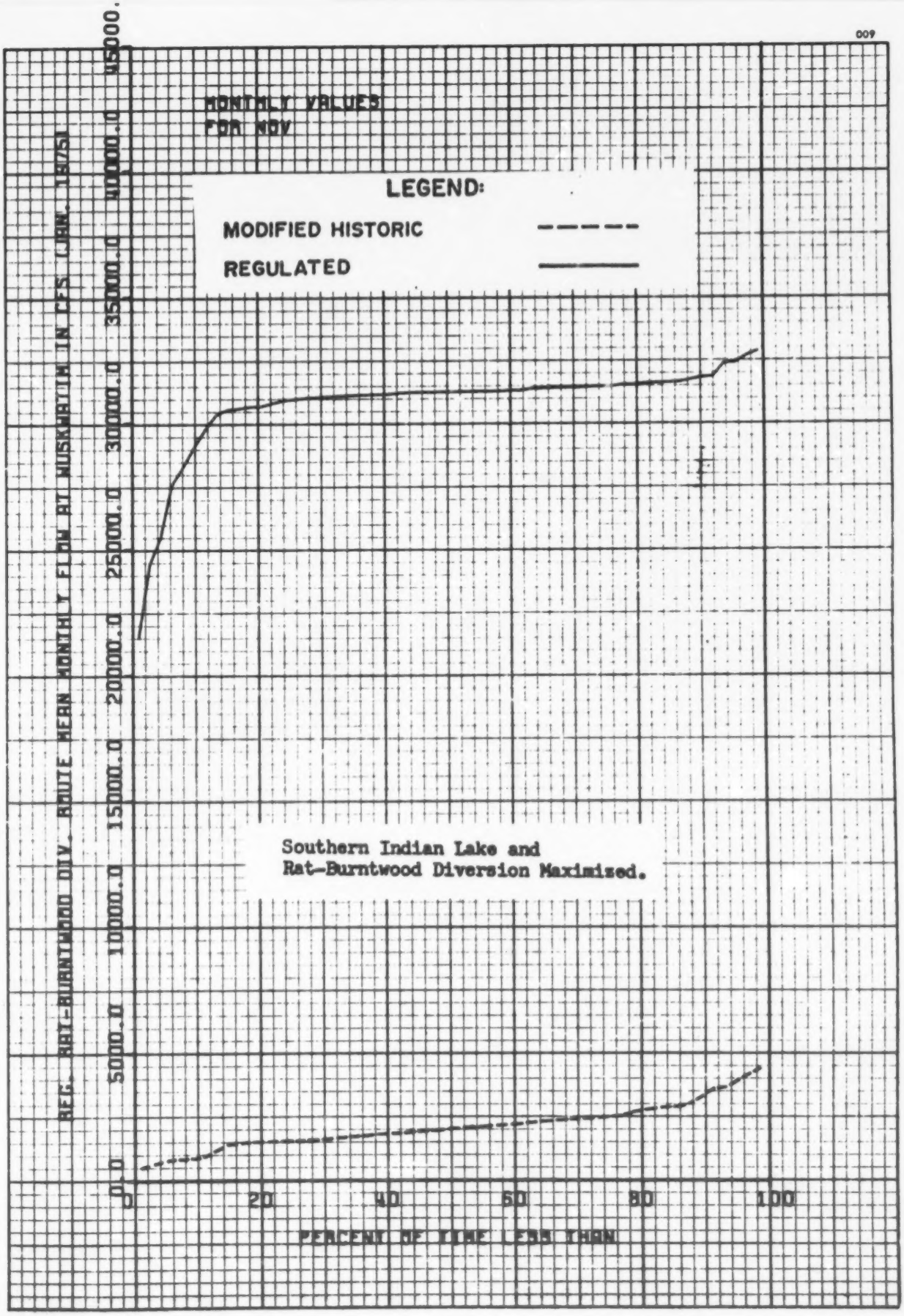

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JRN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

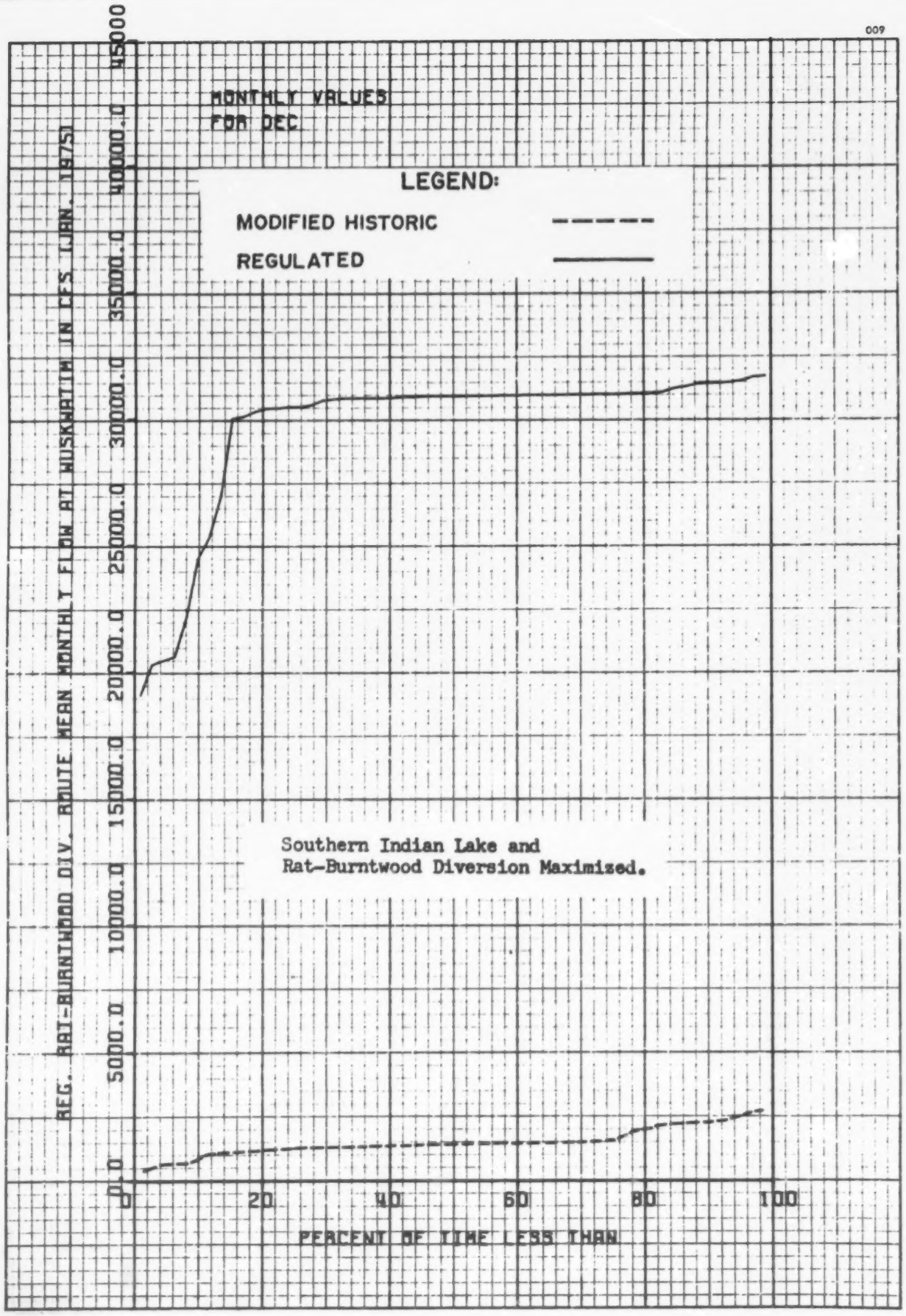

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JAN. 1875)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRAMMIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATIM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRAT IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC.
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
REG. RAT-BURNTWOOD DIV. ROUTE MEAN MONTHLY FLOW AT MUSKRATTM IN CFS (JAN. 1975)
0.0
5000.0
10000.0
15000.0
20000.0
25000.0
30000.0
35000.0
40000.0
45000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SECTION 4

SOUTHERN INDIAN LAKE STUDY AREA

Southern Indian Lake Levels

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SOUTHERN INDIAN LAKE LEVELS HYDROLOGIC PERIOD 1928 - 1966

MODIFIED HISTORIC LEVELS

- FLUCTUATIONS IN PERCENT -

Range 000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-1	5	89	5	76	37	50	50	50	58	13	47	0	79	0	61	29	26	61	5	76	8	86	5	89
1-2	0	5	0	18	0	13	0	0	26	0	26	0	13	0	5	5	3	11	5	13	3	3	0	5
2-4	0	0	0	0	0	0	0	0	3	0	26	0	8	0	0	0	0	0	0	0	0	0	0	0
4-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- LEVELS IN FEET -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	834.38	834.14	834.25	833.98	834.00	834.81	835.32	835.73	835.53	834.87	834.68	834.52	833.98
AVERAGE	835.88	835.44	835.13	835.08	835.71	837.06	837.87	837.89	837.57	837.10	836.73	836.35	836.48
MAXIMUM	839.16	838.06	836.58	836.23	838.11	841.89	842.81	841.73	841.12	840.83	840.35	839.91	842.81

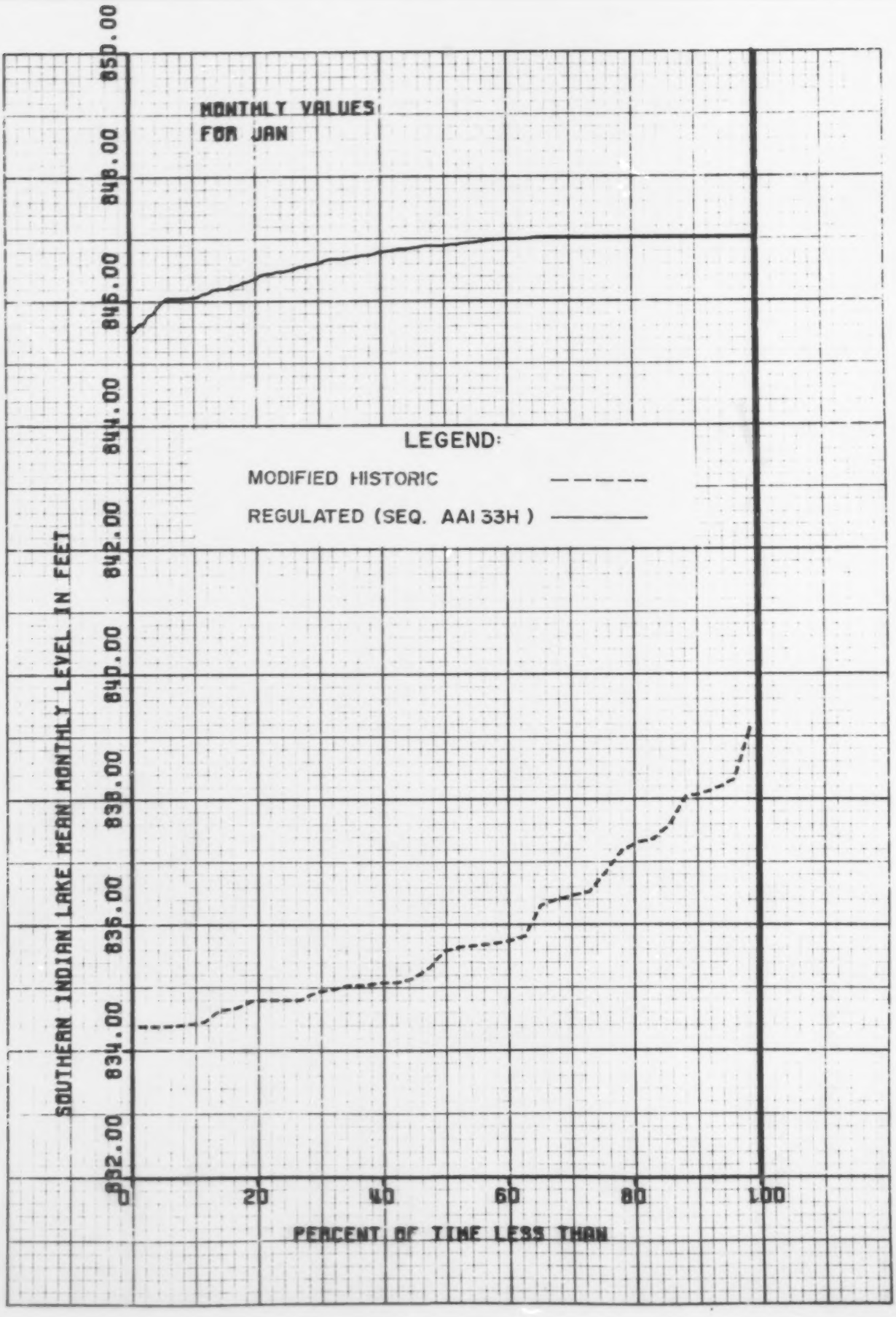
POST DIVERSION LEVELS

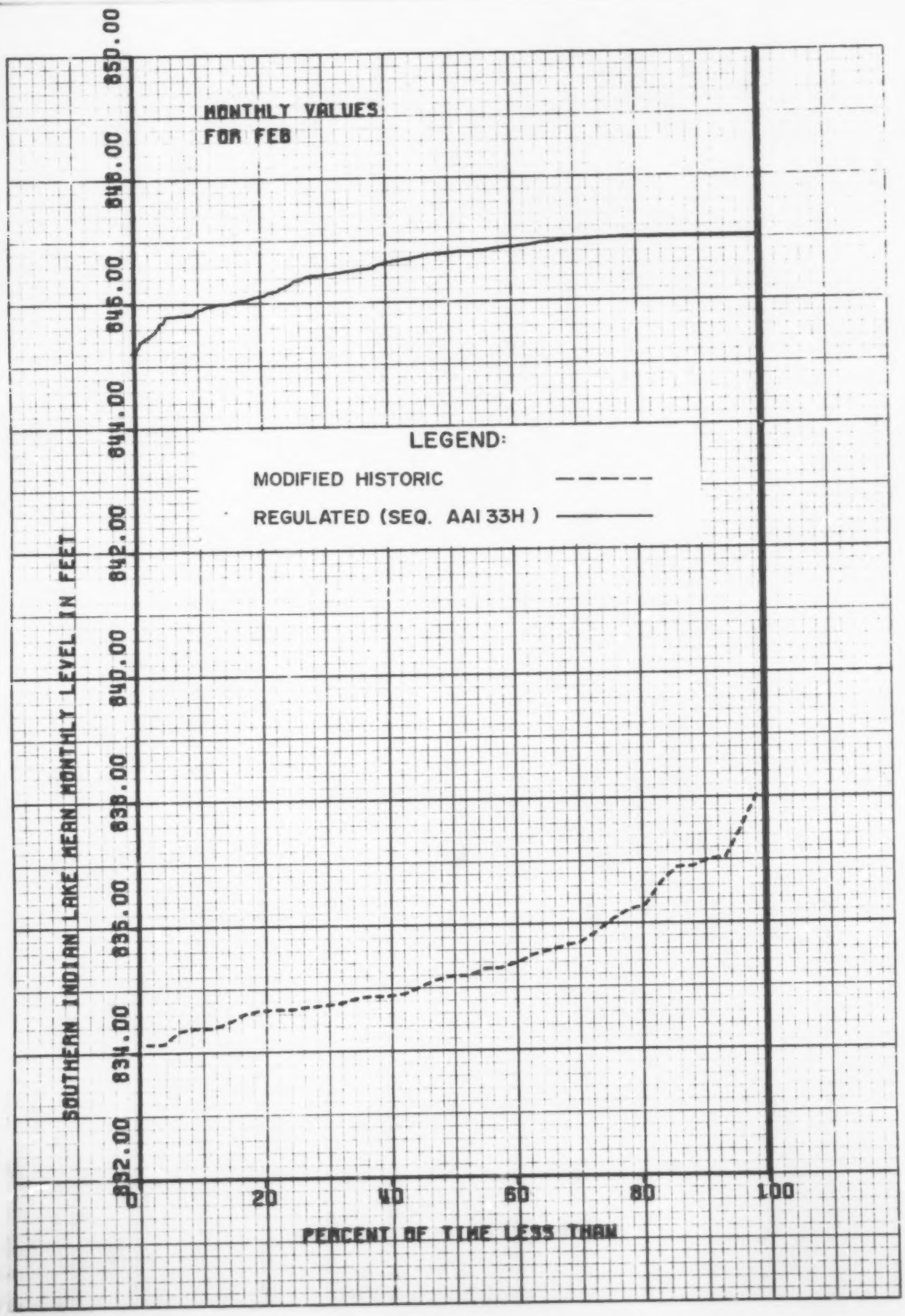
- FLUCTUATIONS IN PERCENT -

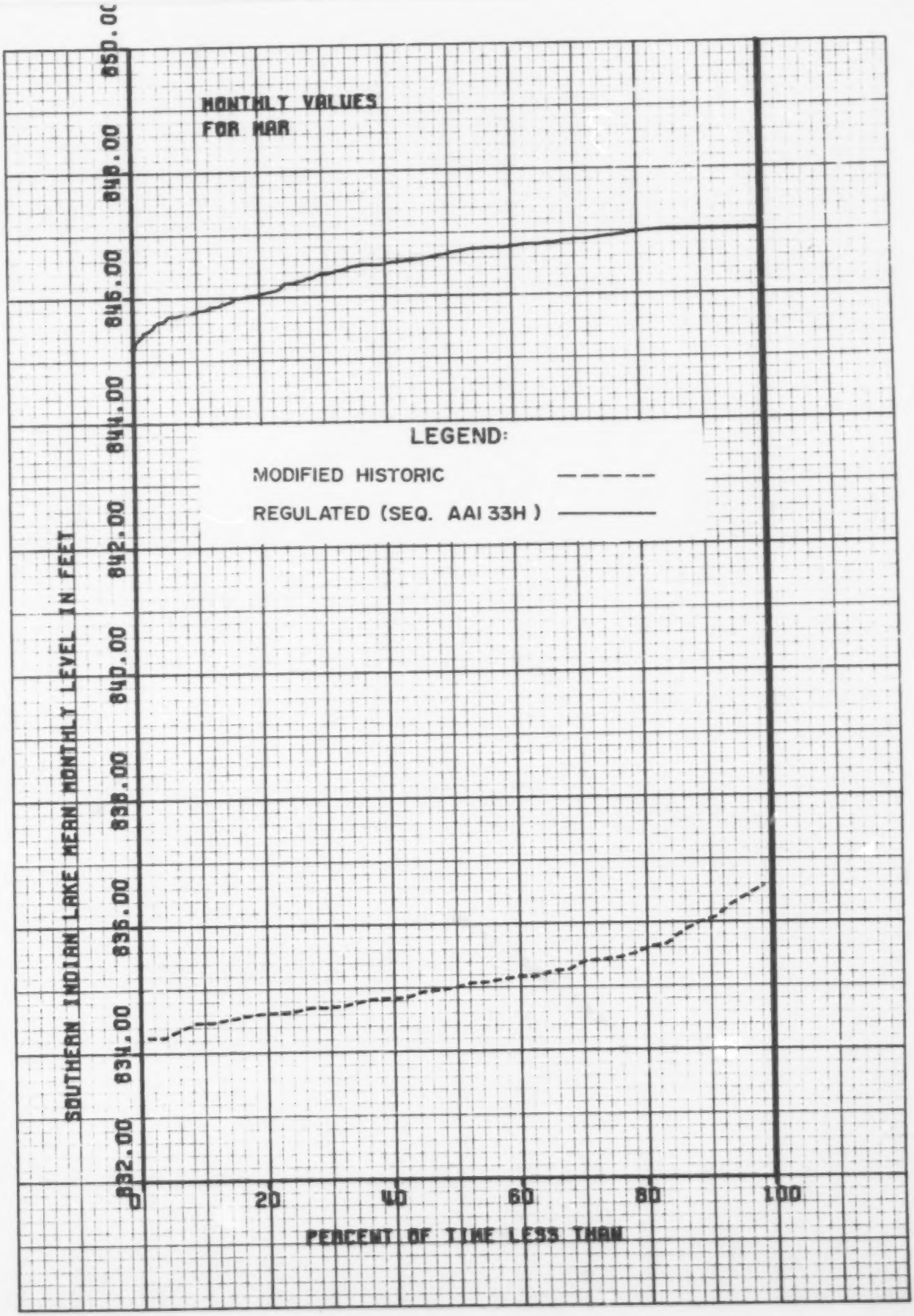
Range 000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-1	36	64	28	72	38	62	78	22	95	5	100	0	100	0	100	0	97	3	79	21	68	32	47	53
1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

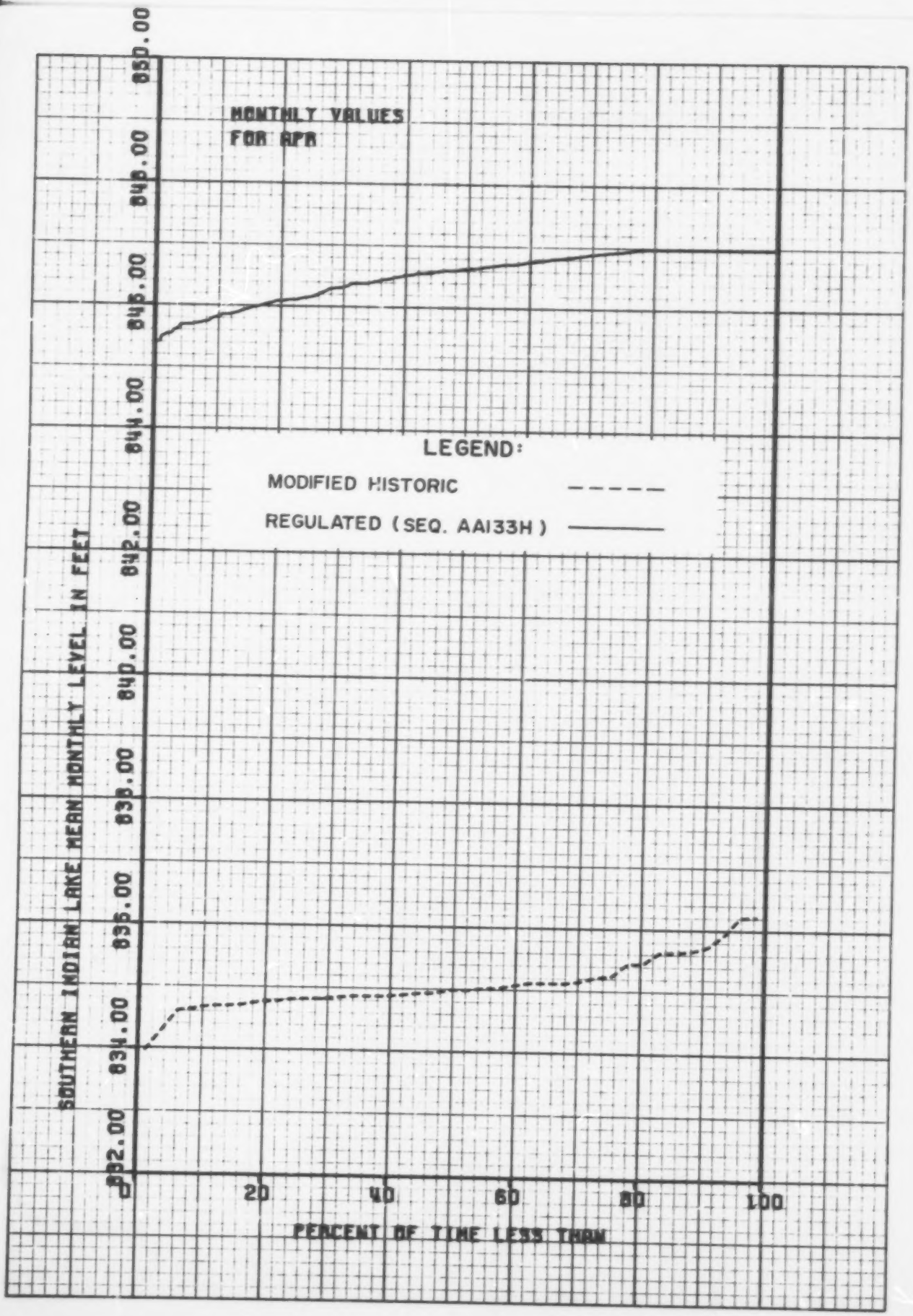
- LEVELS IN FEET -

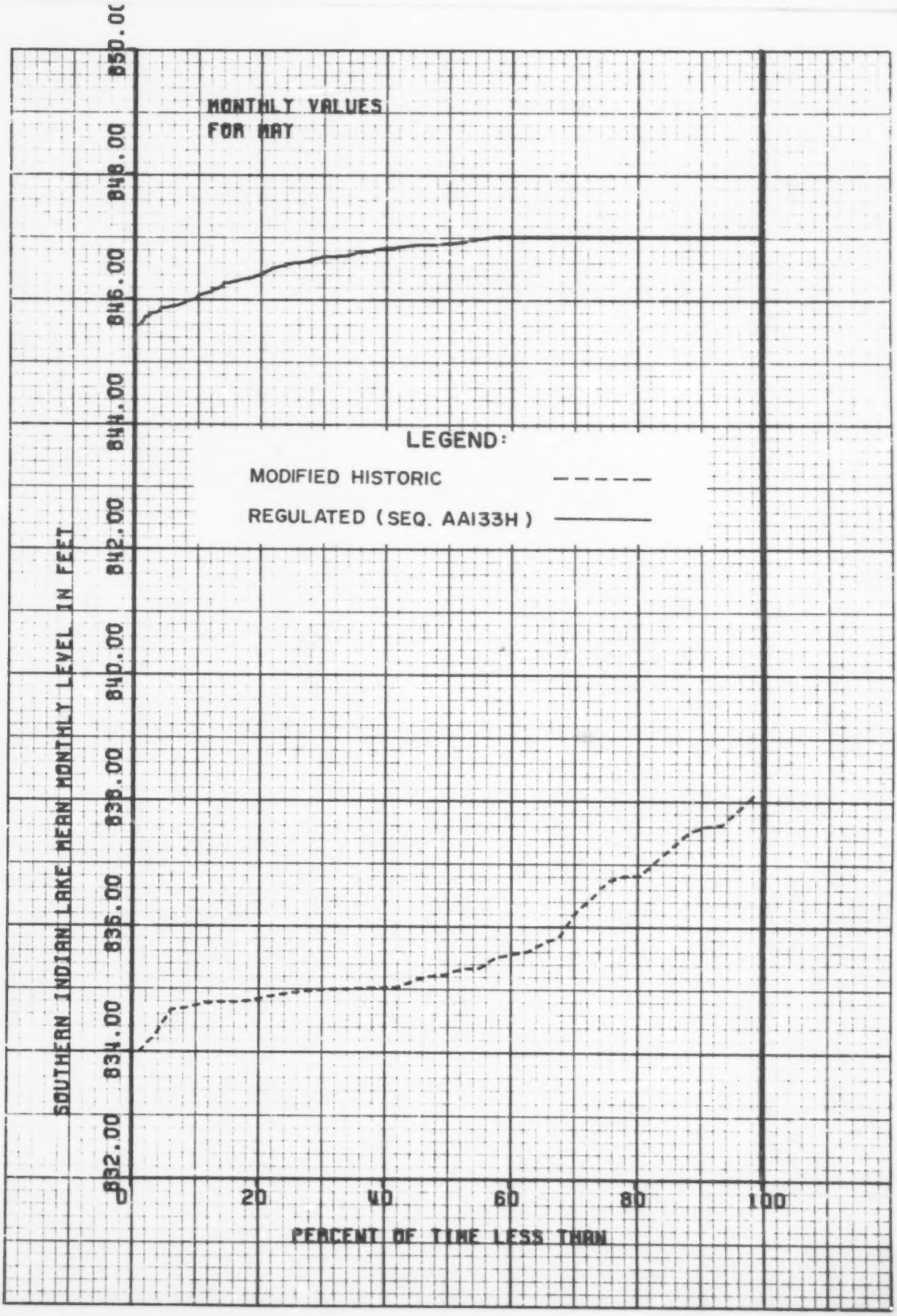
	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	845.49	845.19	845.17	845.34	845.54	845.95	846.44	846.69	846.88	846.47	846.22	845.93	845.17
AVERAGE	846.68	846.57	846.49	846.53	846.71	846.90	846.99	846.99	846.99	846.96	846.91	846.81	846.79
MAXIMUM	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00


MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHEAN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

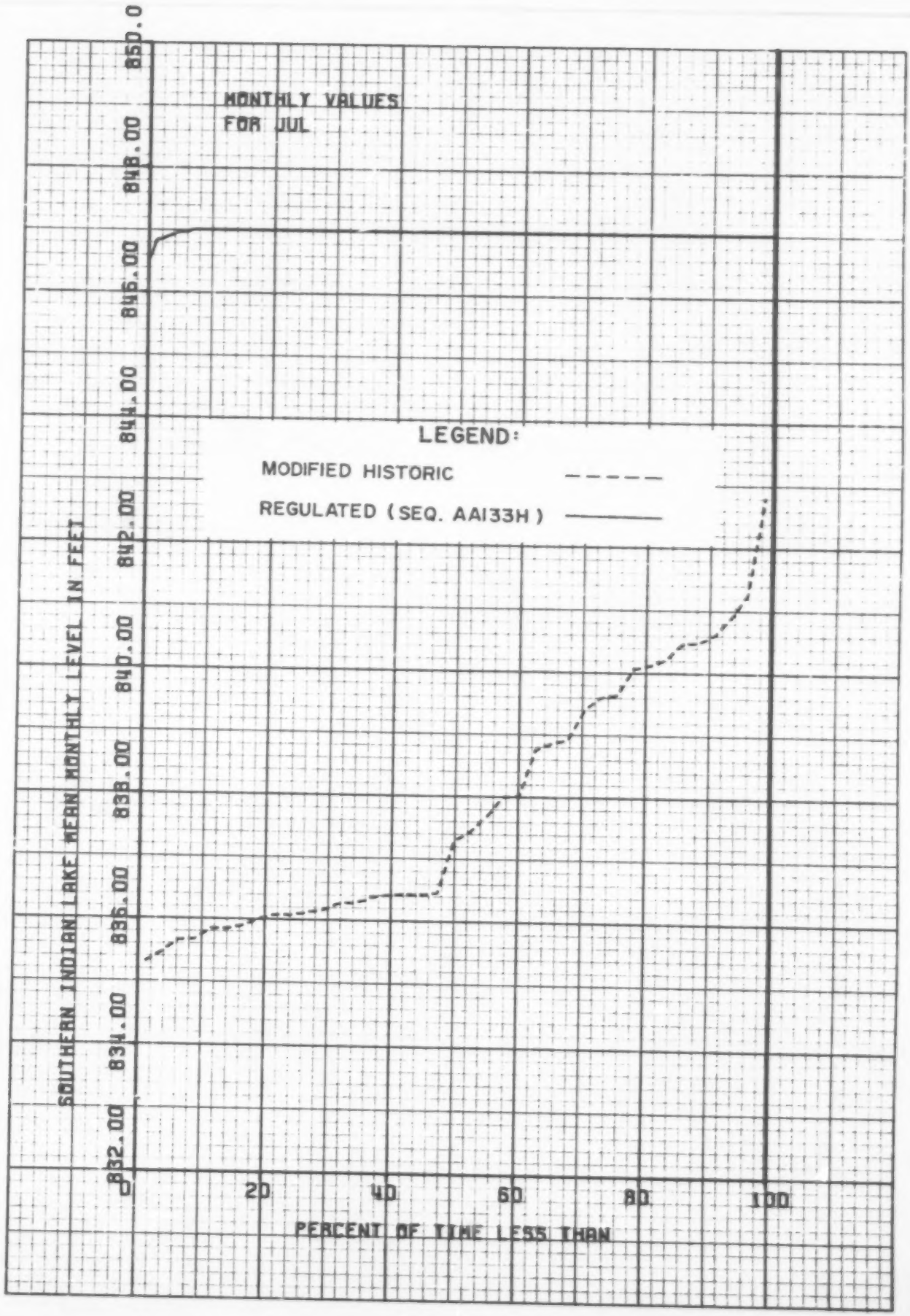

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

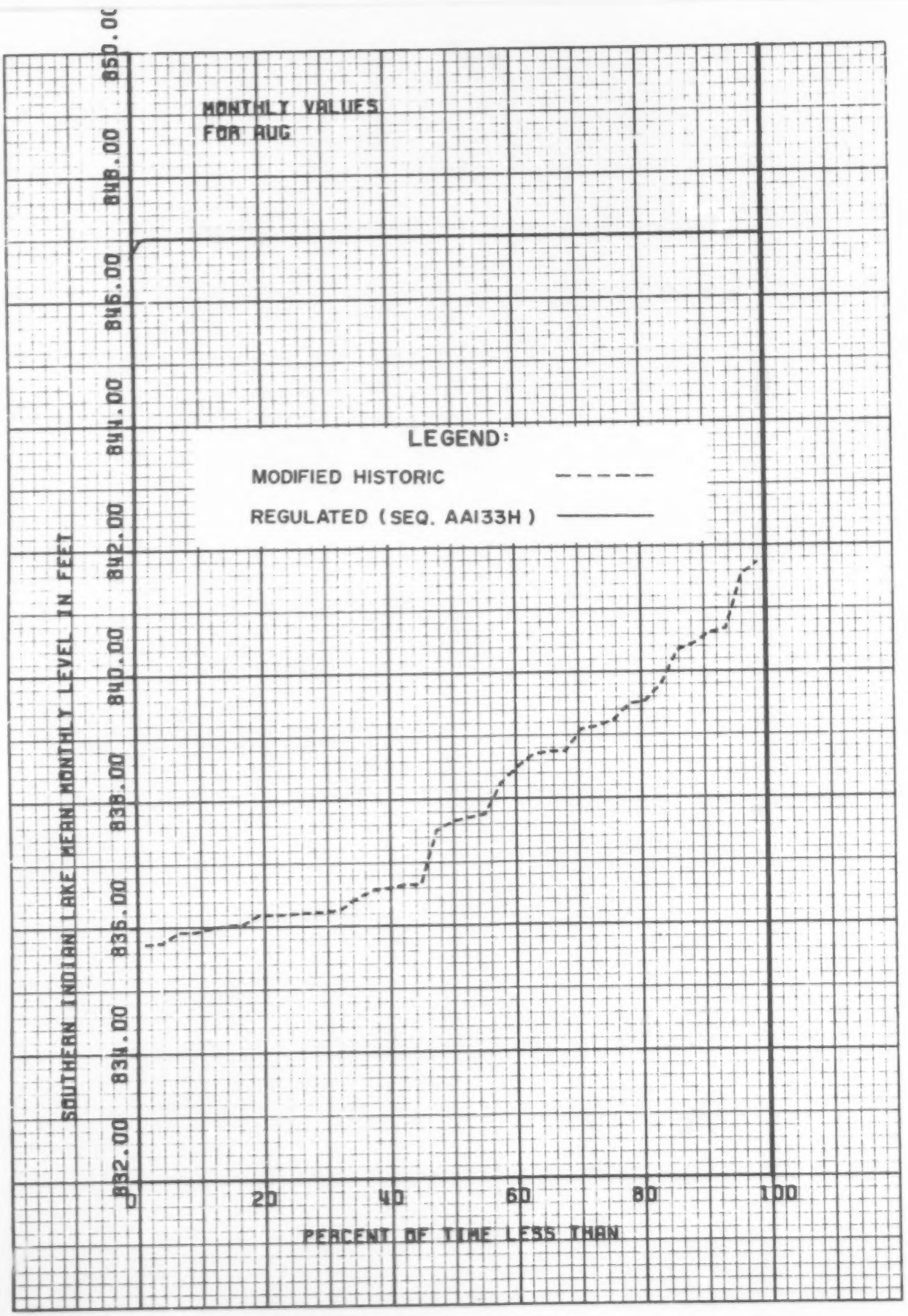

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

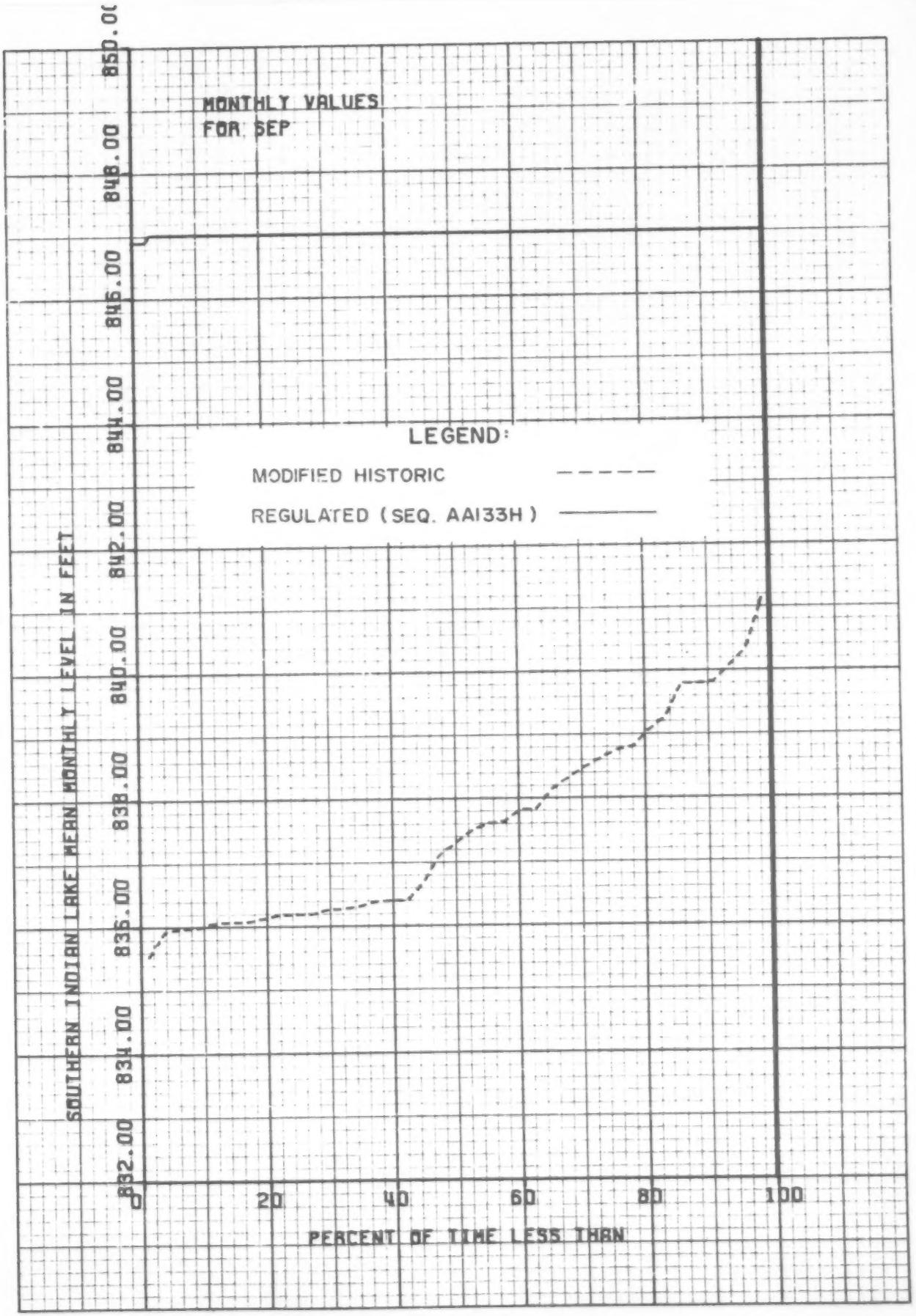

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

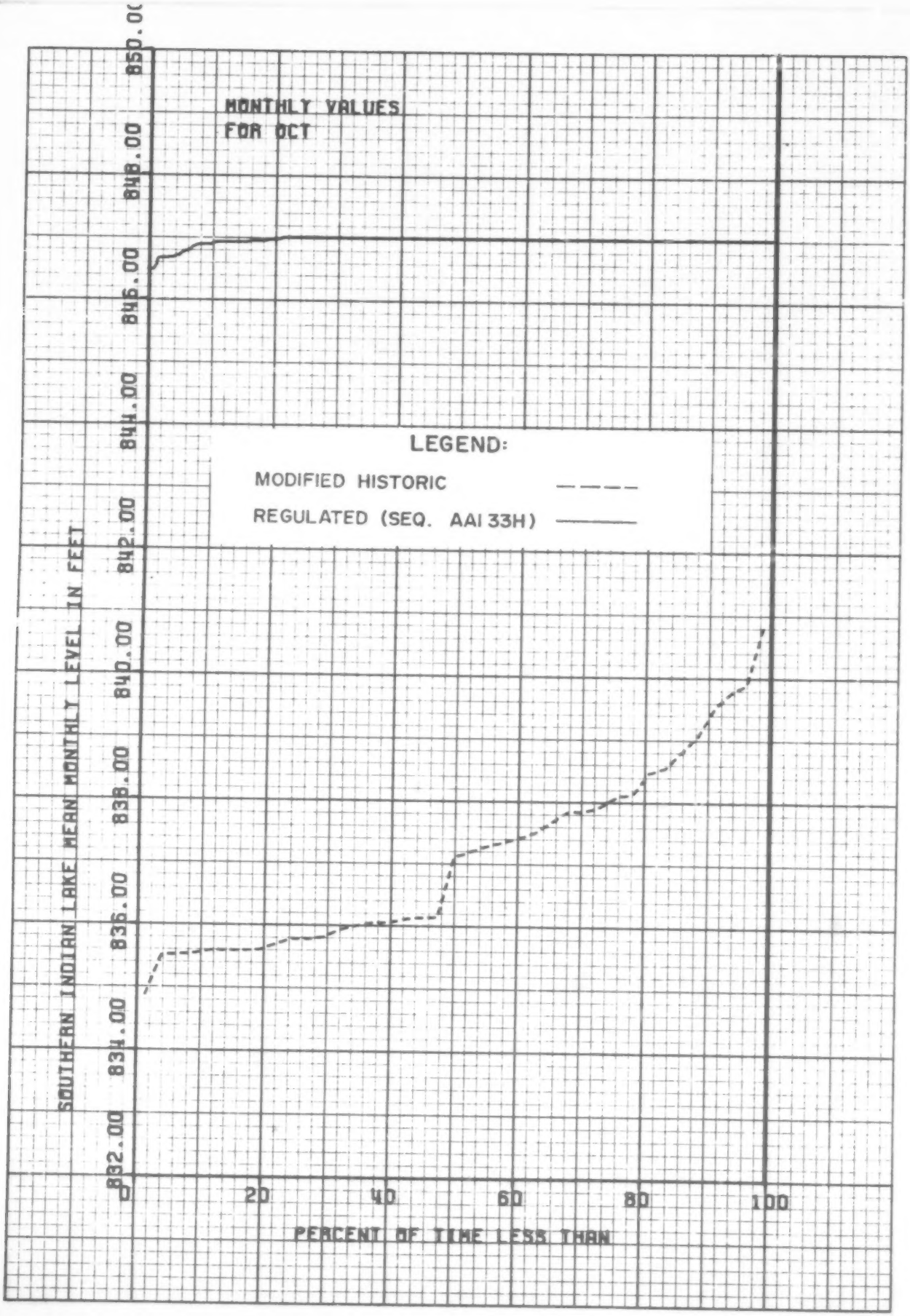

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.0(
20
40
60
80
100
PERCENT OF TIME LESS THAN

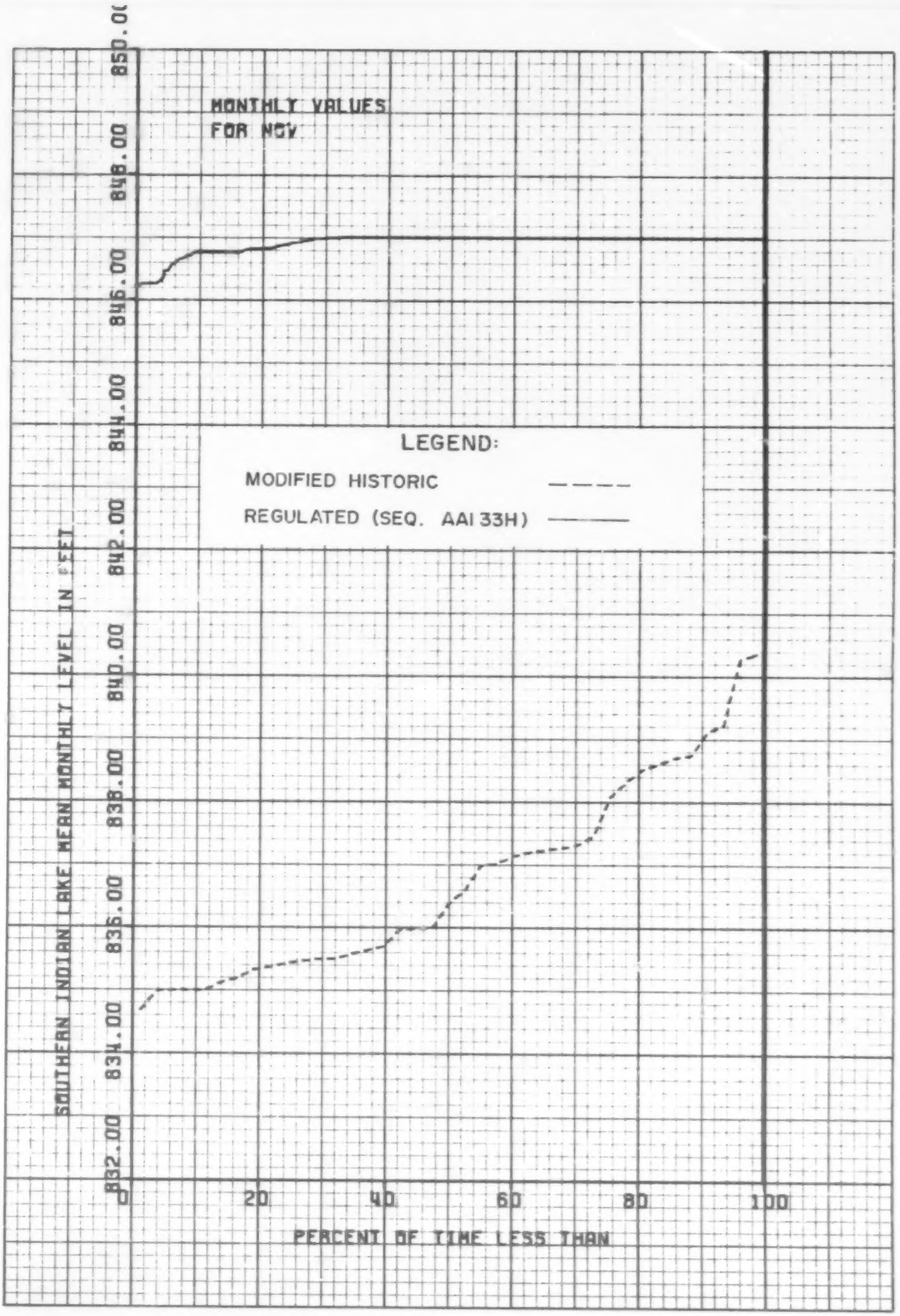
MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

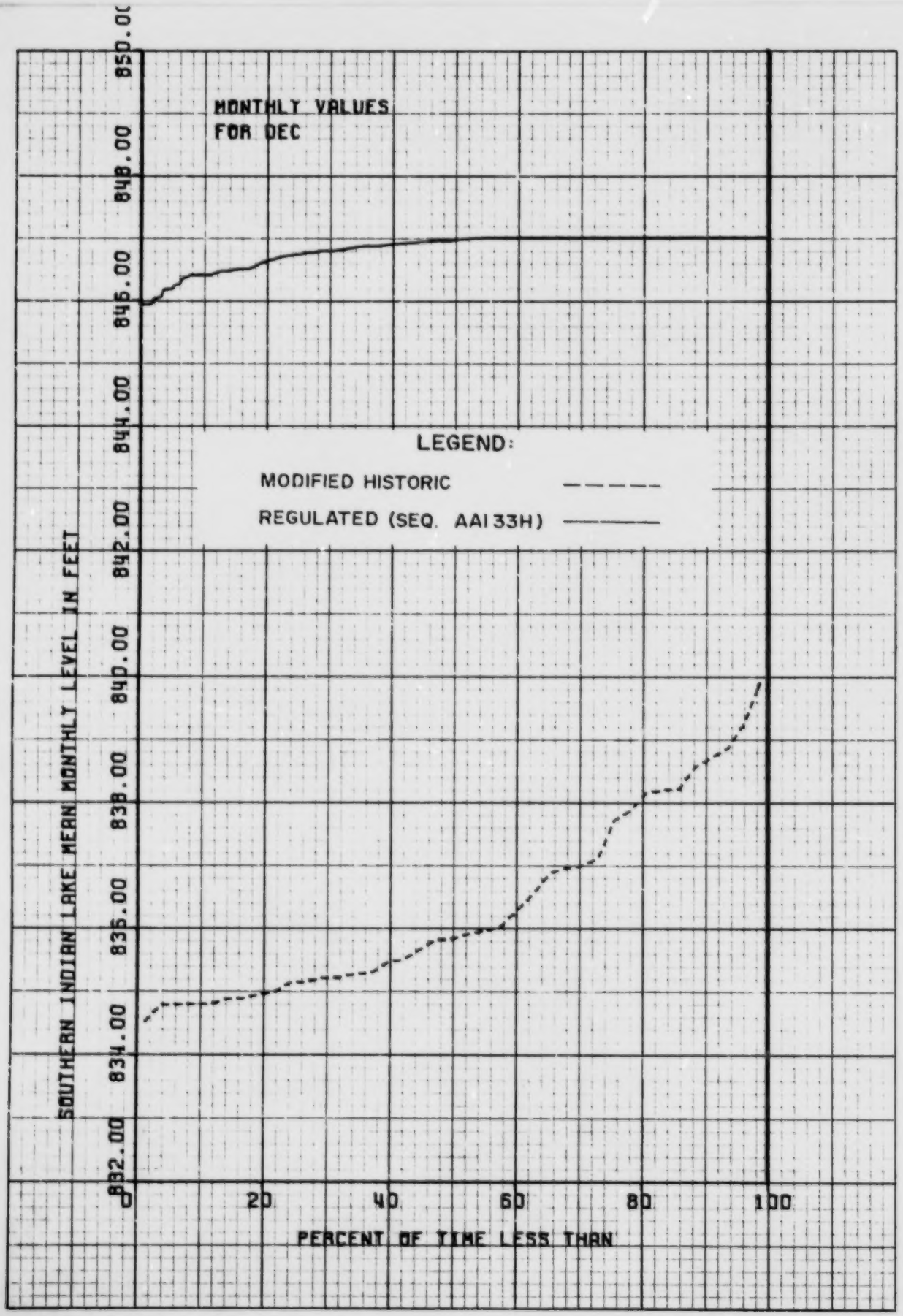

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.0
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHEAN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.0
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.0
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SOUTHERN INDIAN LAKE LEVELS HYDROLOGIC PERIOD 1912 - 1967

MODIFIED HISTORIC LEVELS

- FLUCTUATIONS IN PERCENT -

Range In Feet	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-1	0	75	0	100	68	32	55	45	84	7	7	0	66	5	4	80	4	63	32	64	29	70	11	82
1-2	0	25	0	0	0	0	0	0	9	0	52	0	21	0	0	16	2	29	2	2	0	2	0	7
2-4	0	0	0	0	0	0	0	0	0	0	41	0	7	0	0	0	0	4	0	0	0	0	0	0
4-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- LEVELS IN FEET -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	833.12	832.93	833.03	832.75	833.06	833.69	833.91	833.85	833.02	833.34	833.48	833.63	832.75
AVERAGE	835.40	835.06	835.06	835.06	835.58	837.61	838.47	837.82	836.94	836.81	836.65	836.29	836.40
MAXIMUM	837.08	836.43	836.36	836.60	837.31	840.66	842.48	841.60	840.64	840.00	839.36	838.50	842.48

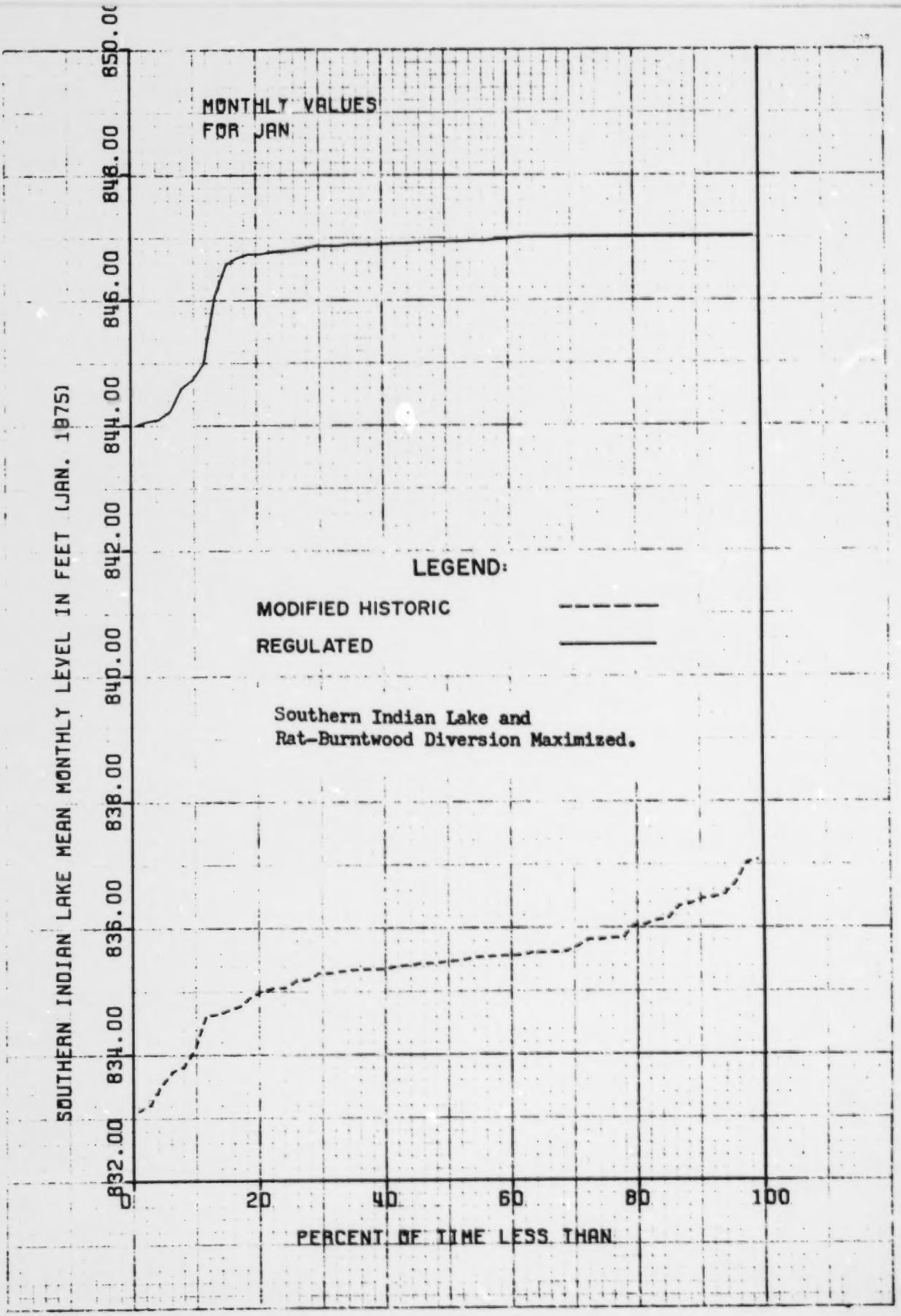
POST DIVERSION LEVELS

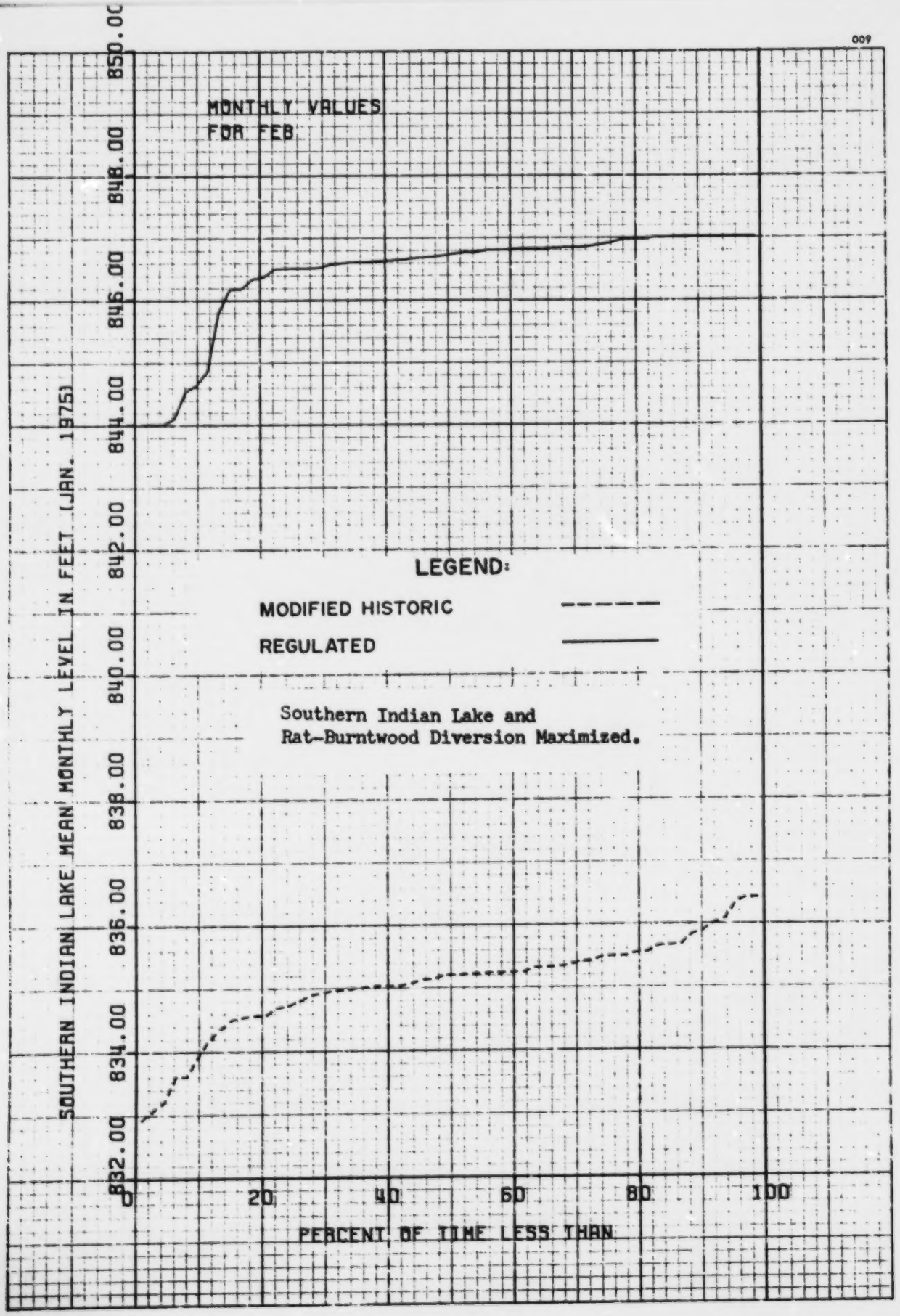
- FLUCTUATIONS IN PERCENT -

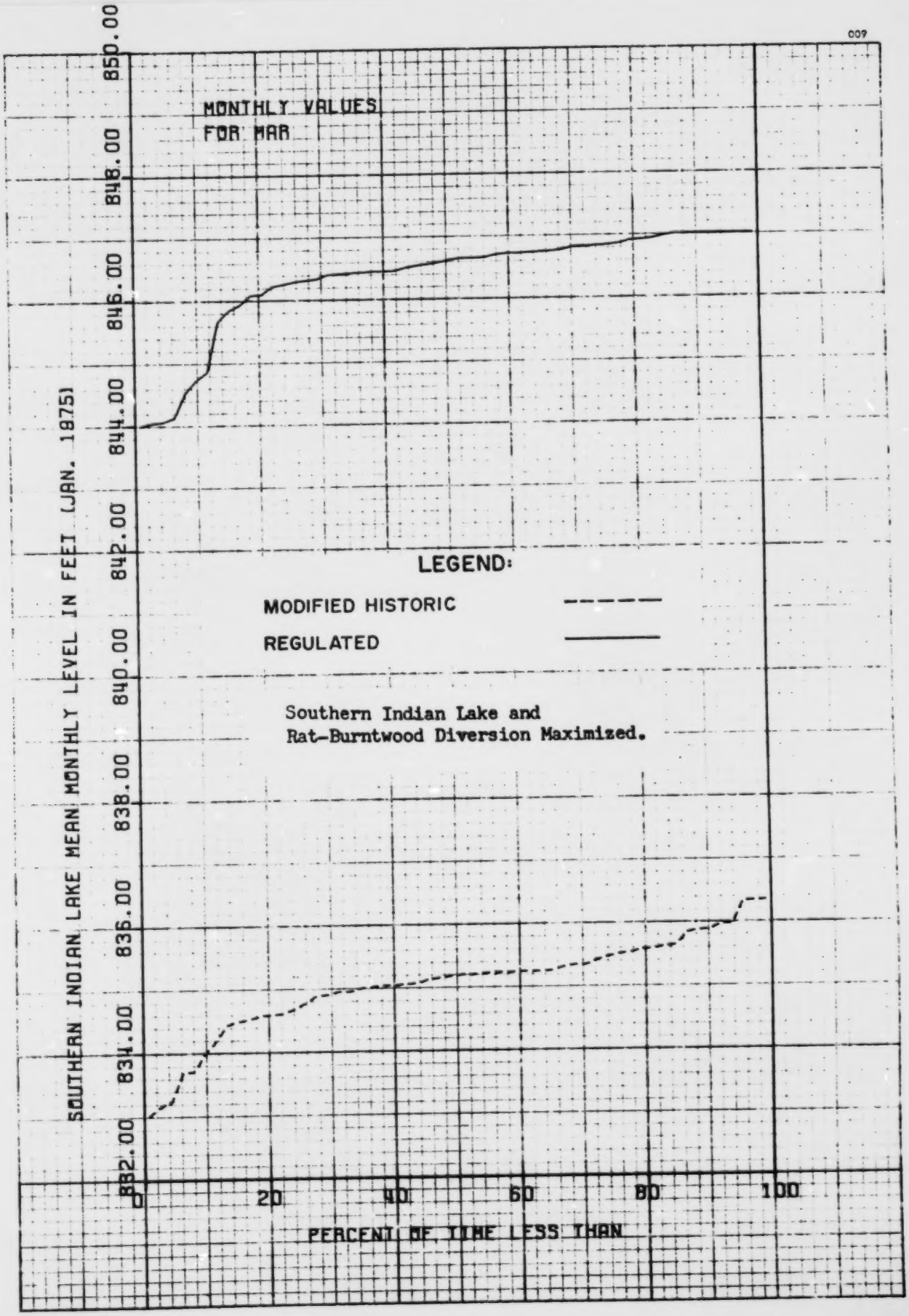
Range In Feet	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-1	36	64	18	82	30	70	34	66	93	7	89	9	79	21	70	30	66	34	73	27	77	23	79	21
1-2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

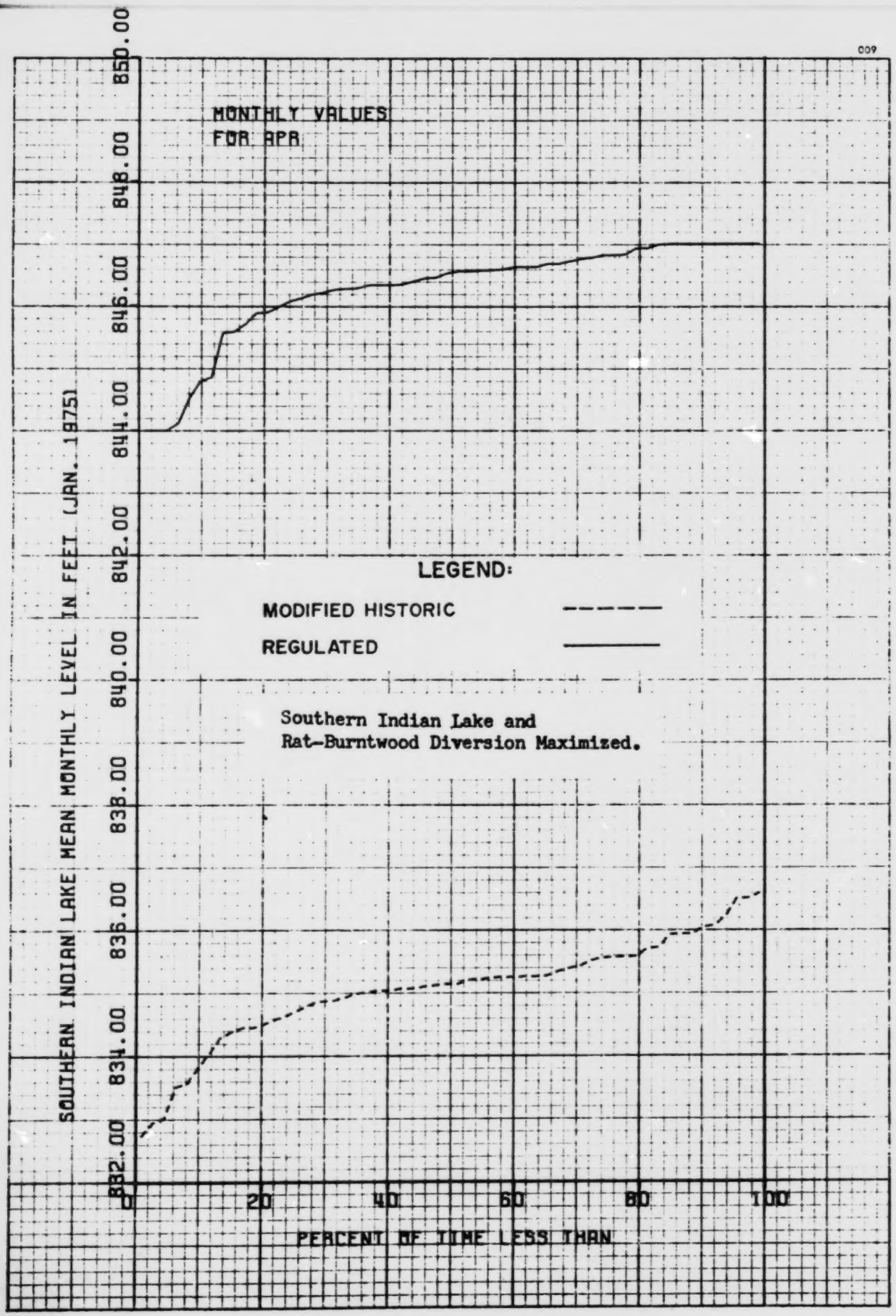
- LEVELS IN FEET -

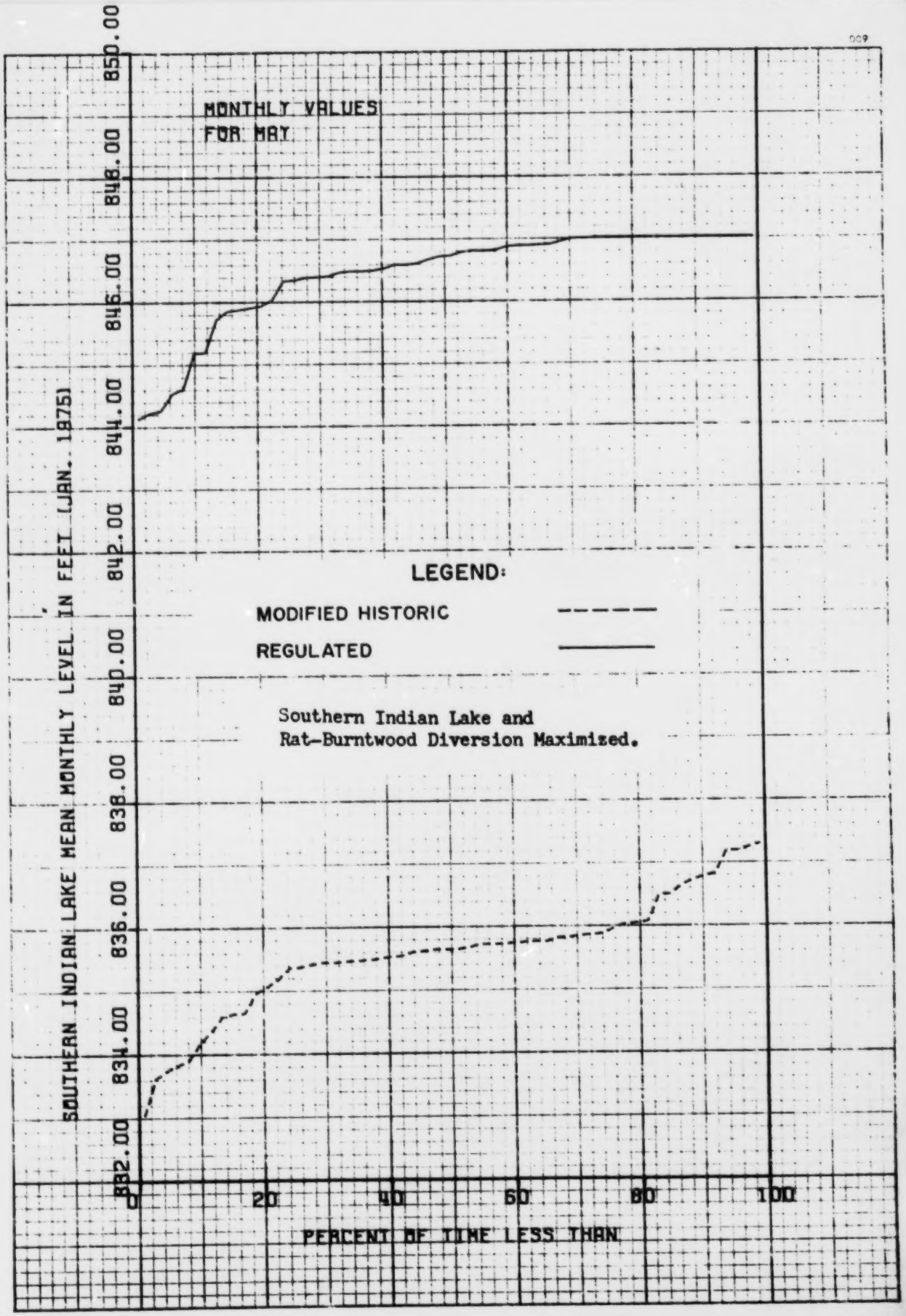
	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	844.00	844.00	844.00	844.00	844.13	844.00	844.00	844.00	843.99	844.00	844.00	843.99	843.99
AVERAGE	846.58	846.41	846.32	846.25	846.41	846.66	846.74	846.74	846.72	846.70	846.68	846.69	846.57
MAXIMUM	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00	847.00

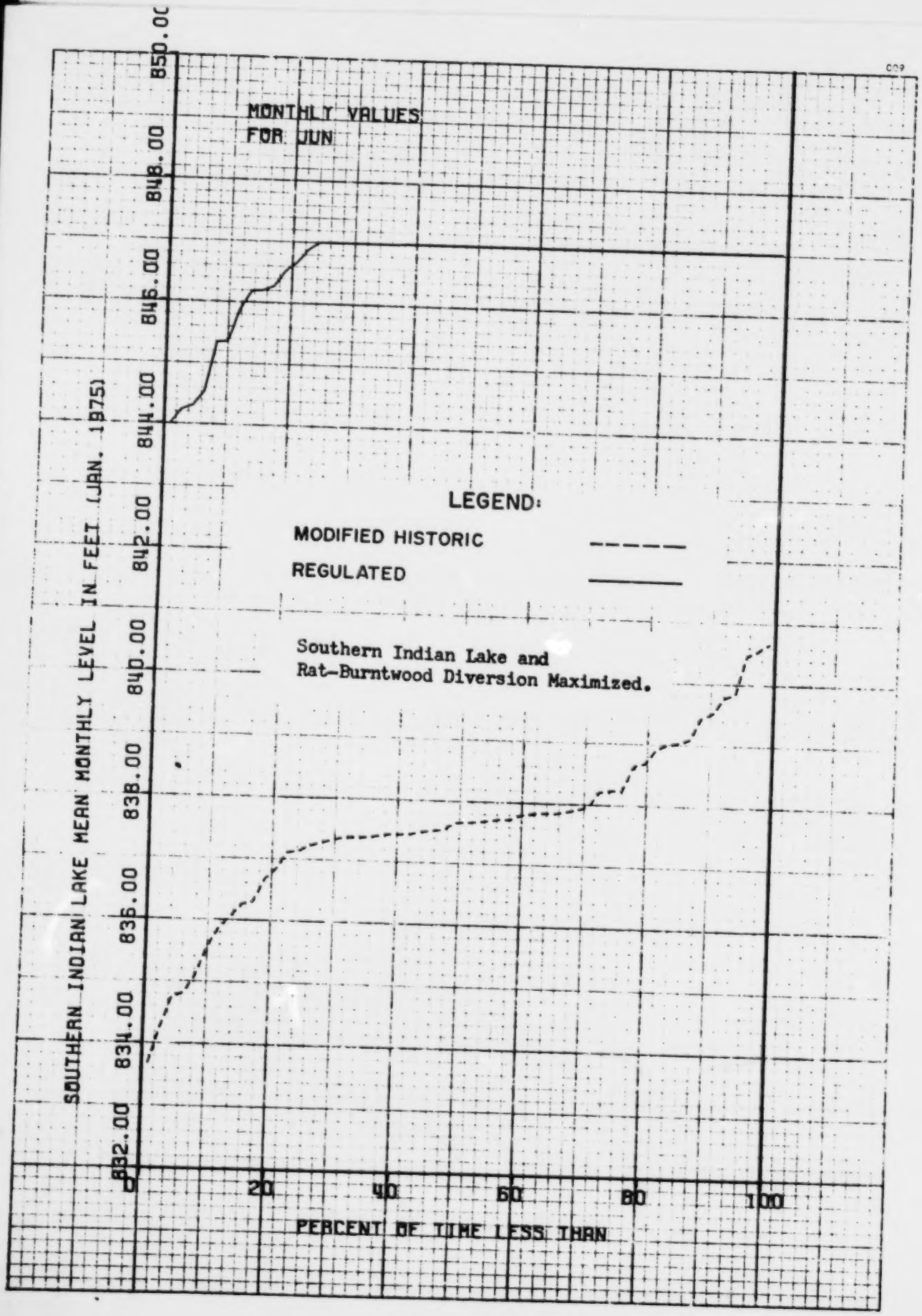

MONTHLY VALUES
FOR JAN.
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1875)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

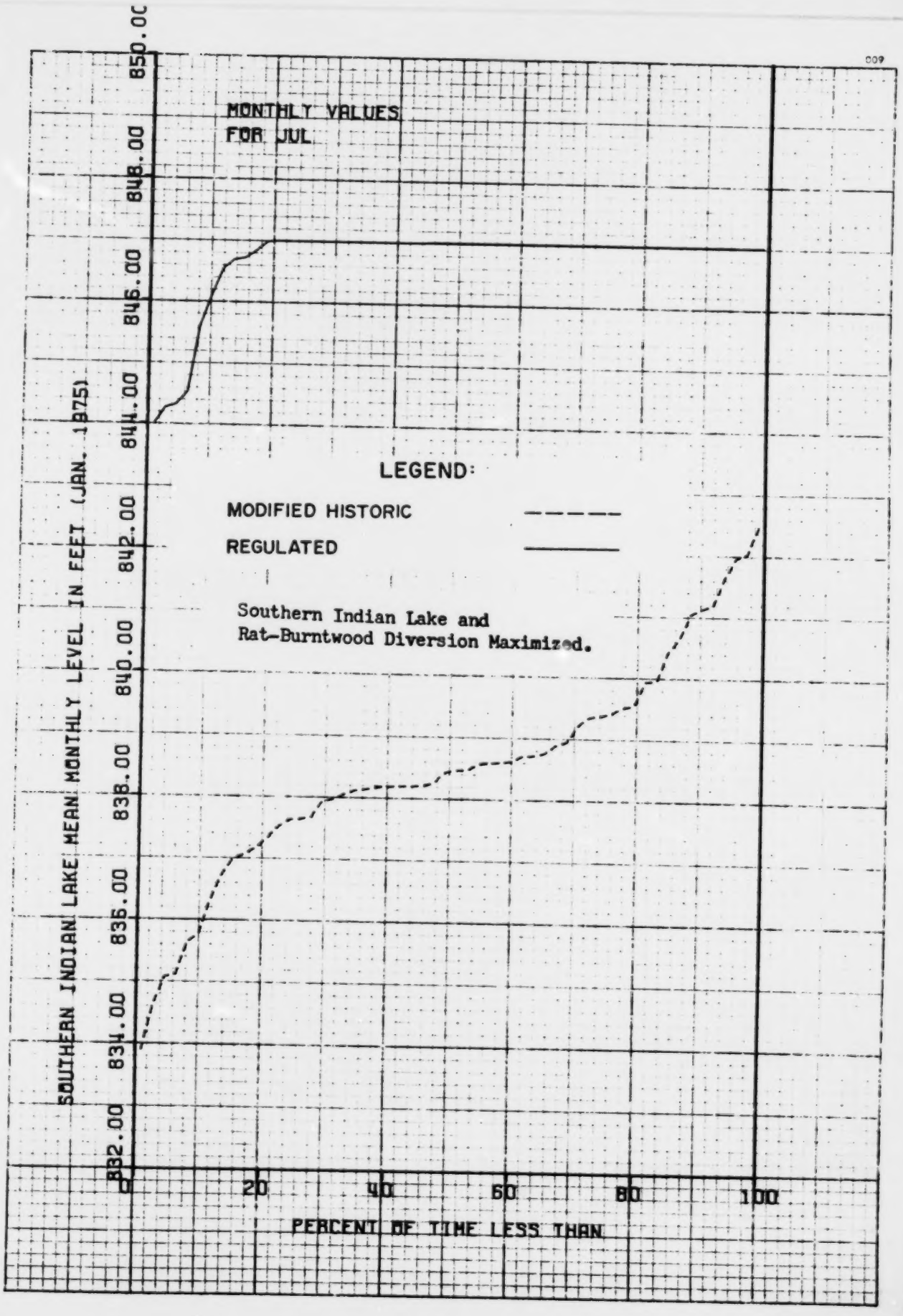

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

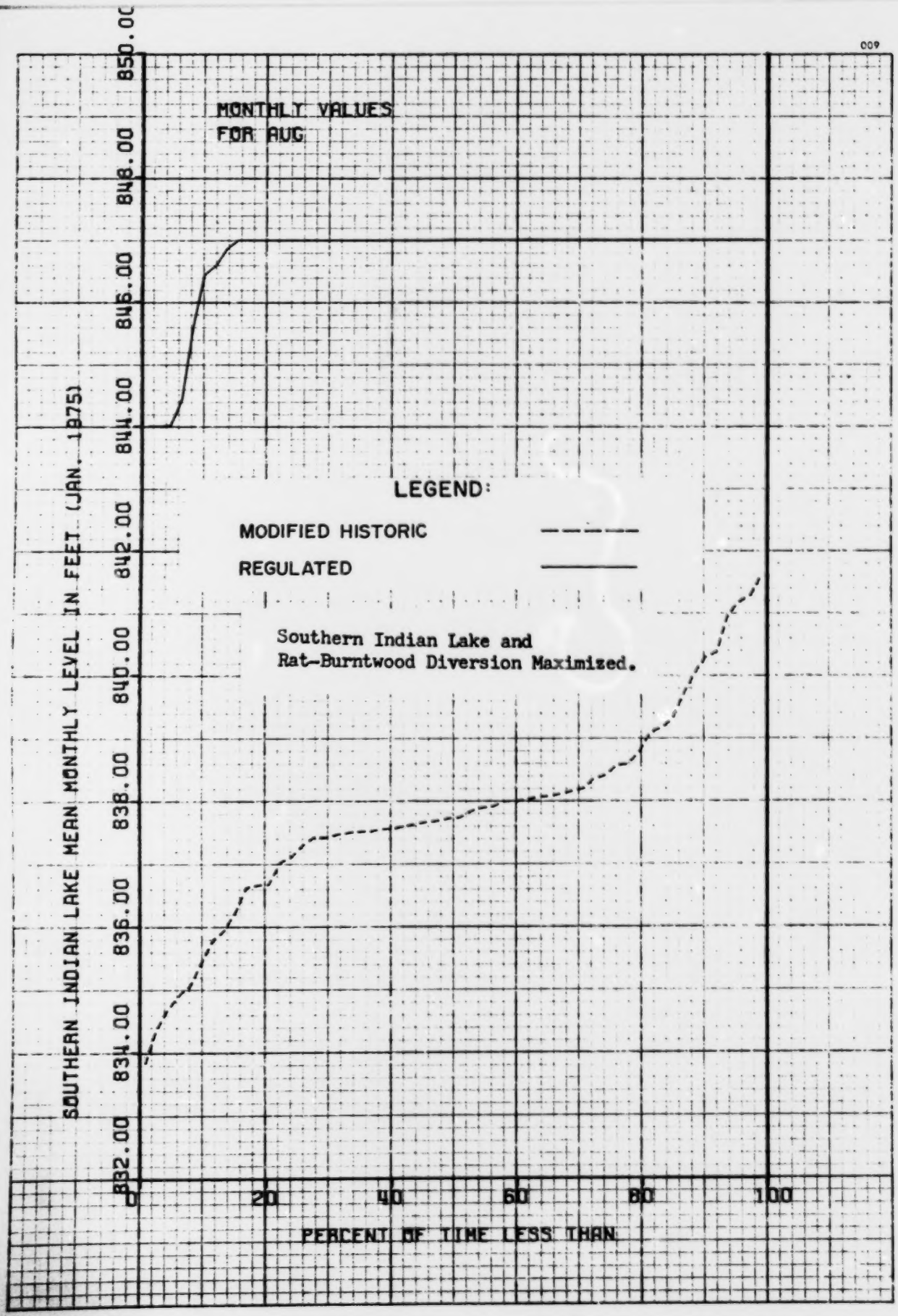

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1875)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

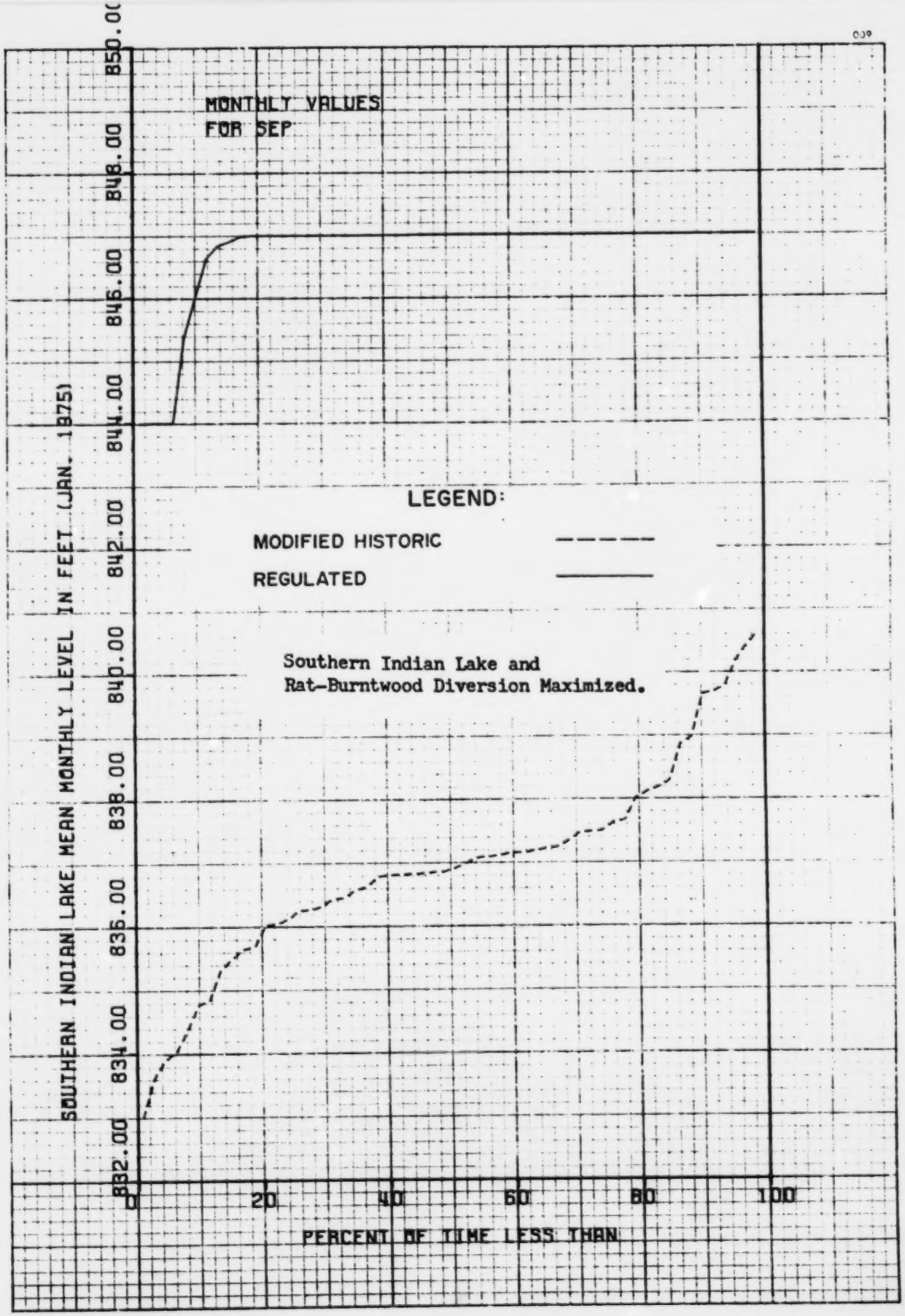

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1875)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

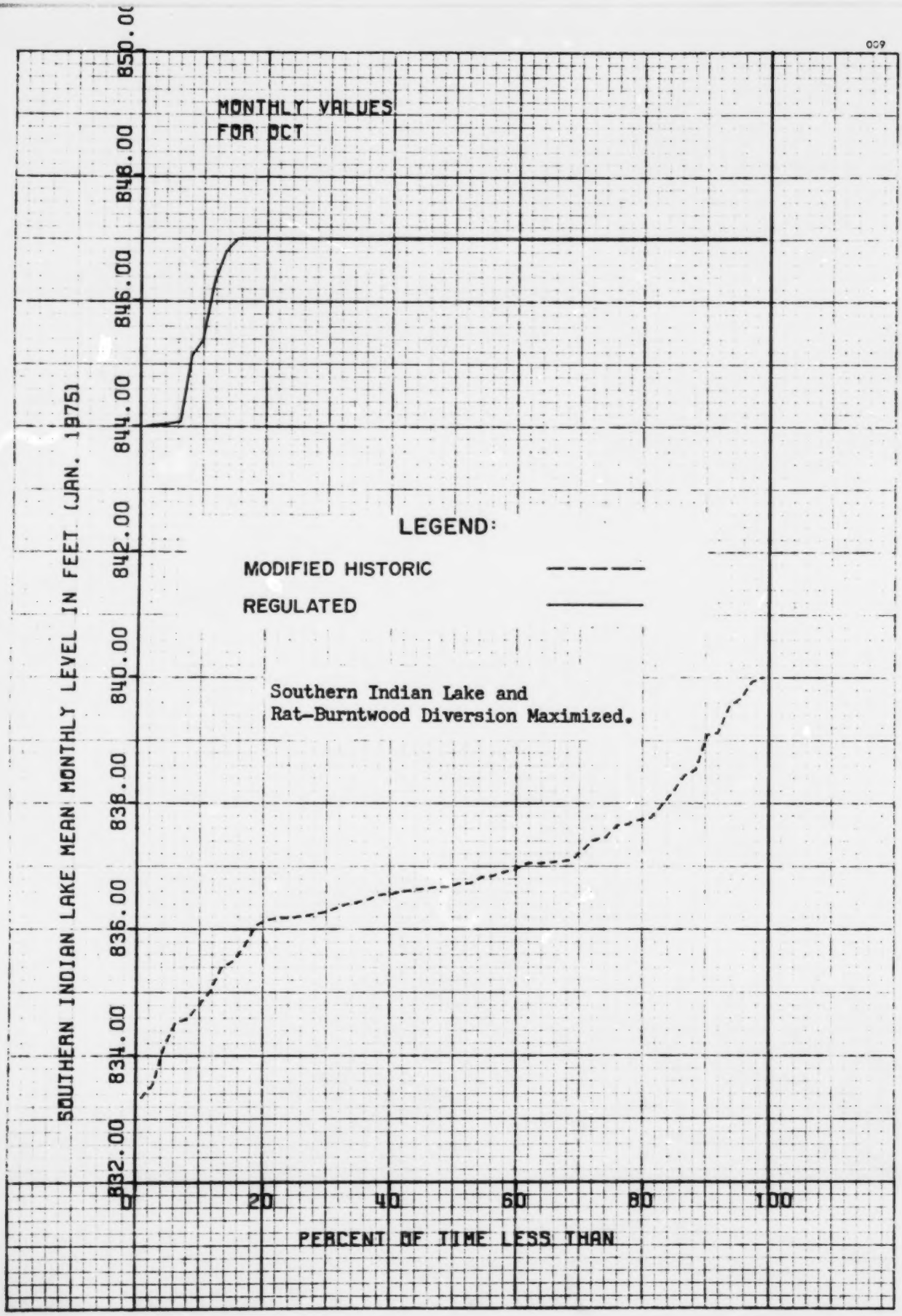

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN., 1875)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

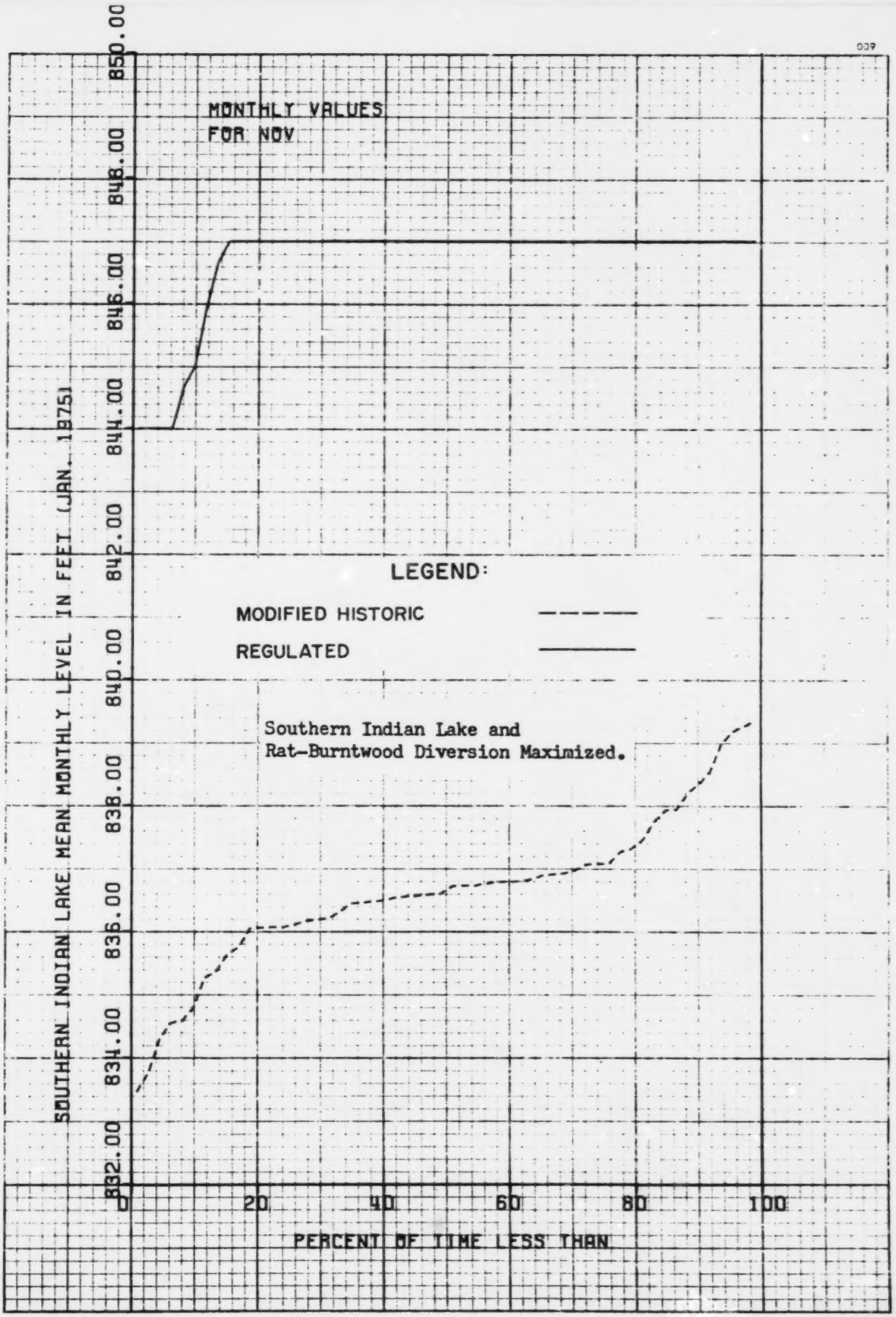

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

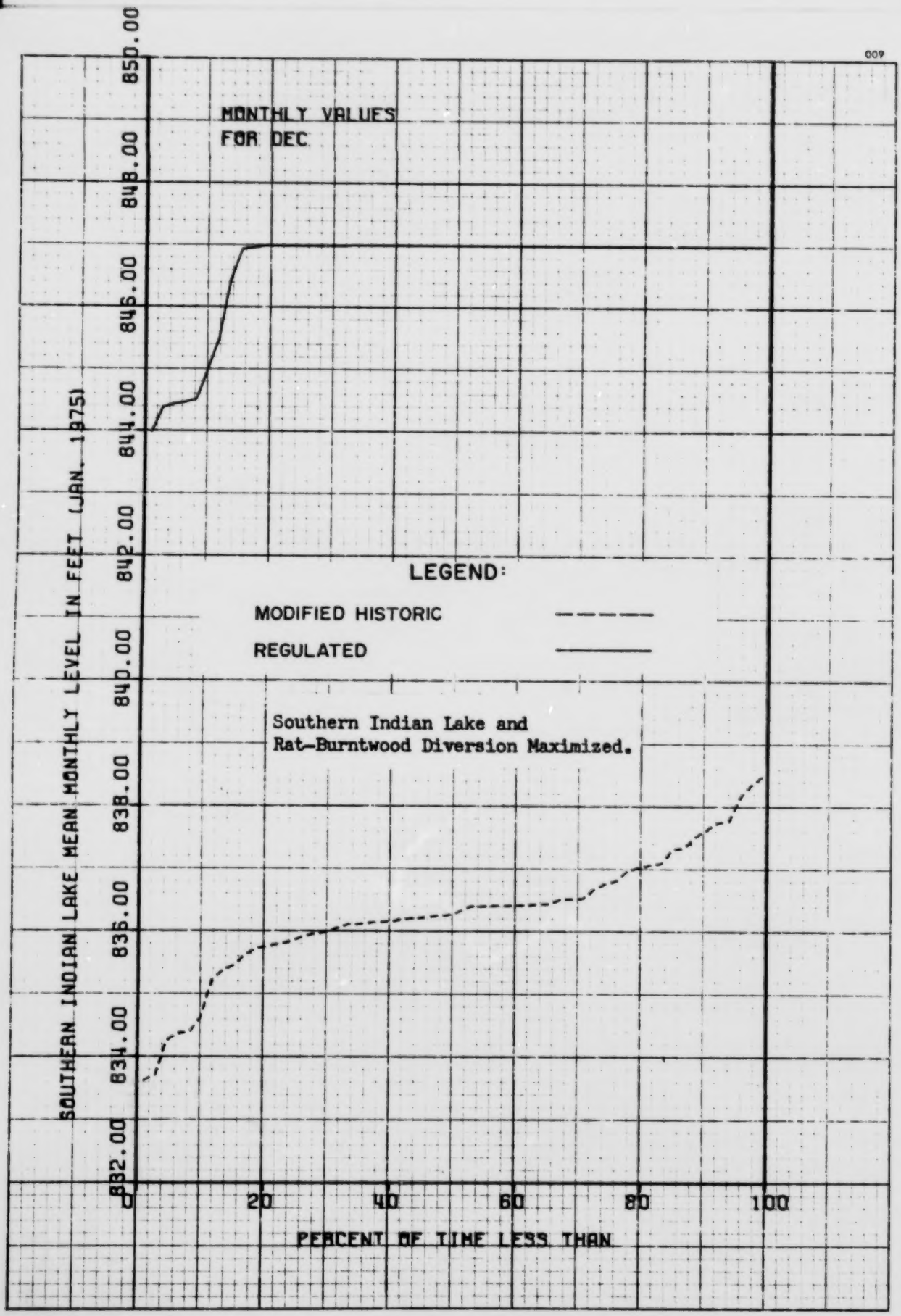

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1875)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1875)
832.00
834.00
836.00
838.00
840.00
842.00
844.00
846.00
848.00
850.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET (JAN. 1975)
850.00
848.00
846.00
844.00
842.00
840.00
838.00
836.00
834.00
832.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SOUTHERN INDIAN LAKE
OUTFLOWS

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SOUTHERN INDIAN LAKE (MISSI FALLS) OUTFLOWS HYDROLOGIC PERIOD 1928-1966

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	5	82	3	74	33	54	51	49	59	13	46	0	62	0	62	26	26	51	3	64	5	85	5	85
5-10	0	13	0	23	0	13	0	0	21	0	23	0	28	0	5	3	3	13	8	23	5	5	0	10
10-20	0	0	0	0	0	0	0	0	8	0	28	0	10	0	0	5	0	8	0	3	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

													ANNUAL
MINIMUM	24277	23200	23718	22493	22597	26151	28787	31070	29979	26422	25607	24905	22493
AVERAGE	32164	29666	27906	27610	31037	38961	44143	44132	41861	38948	37105	34771	35692
MAXIMUM	51645	44609	35874	33902	44902	73906	83101	72334	66716	64164	59992	56430	83101

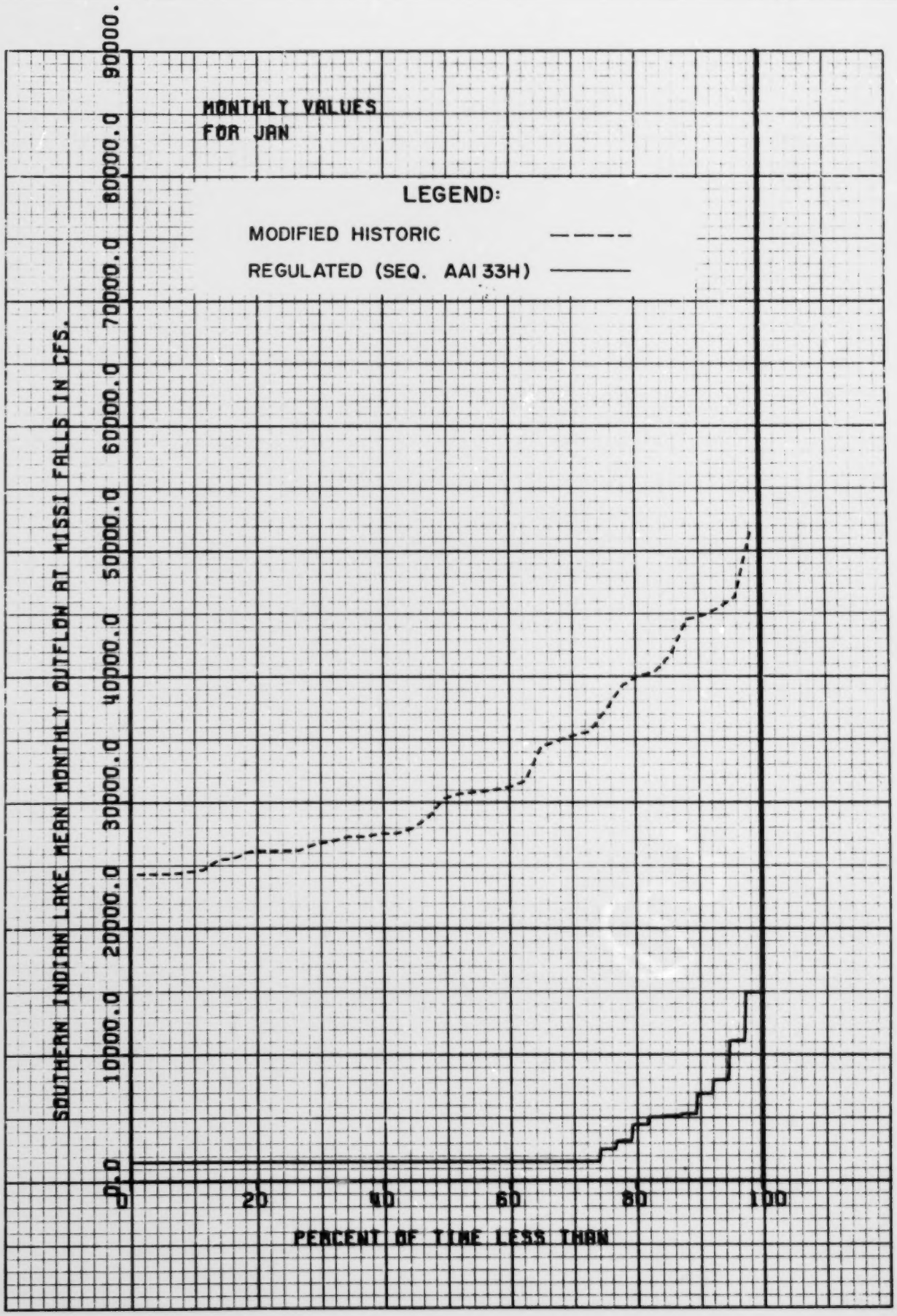
POST DIVERSION FLOWS

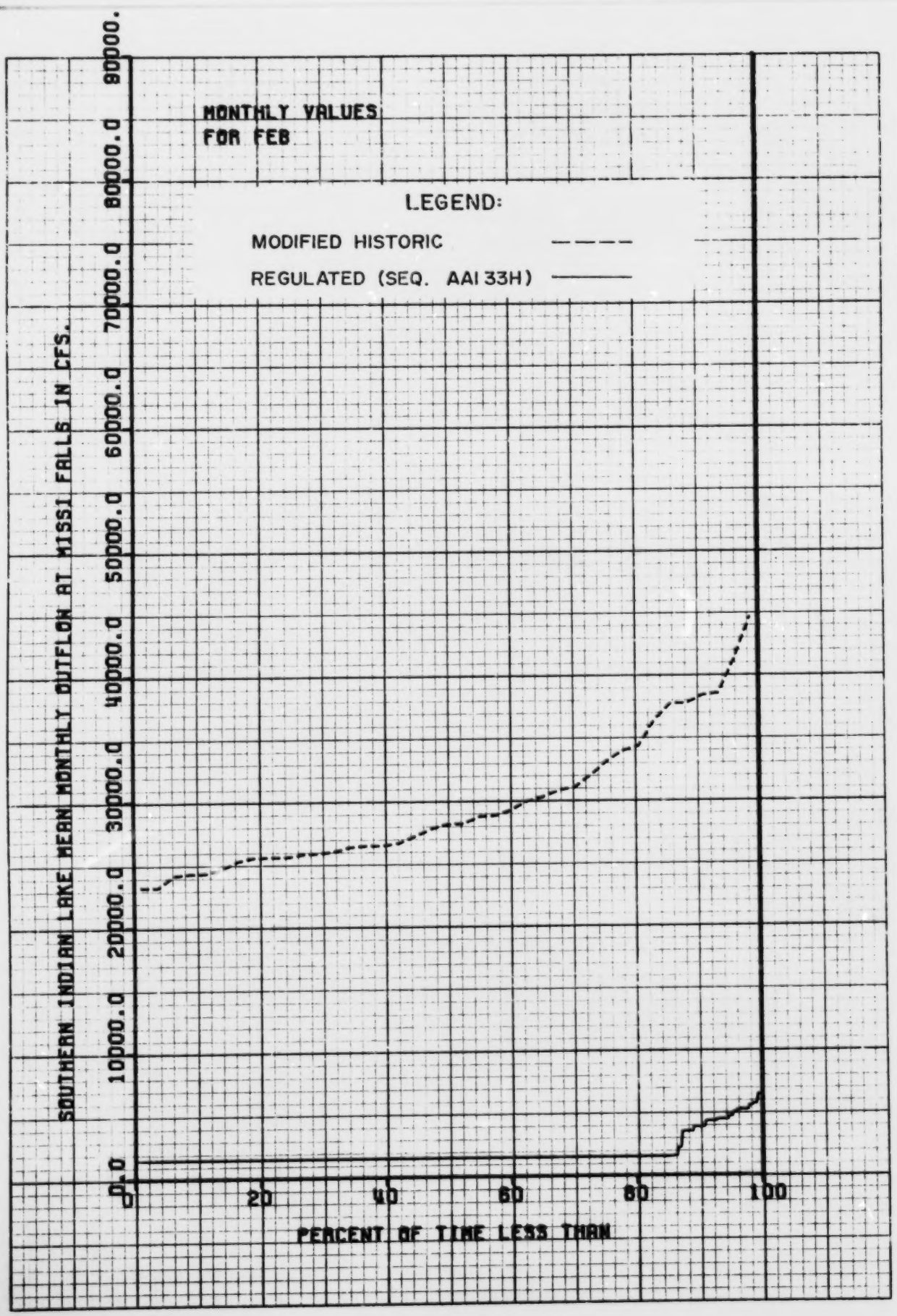
- FLUCTUATIONS IN PRESENT -

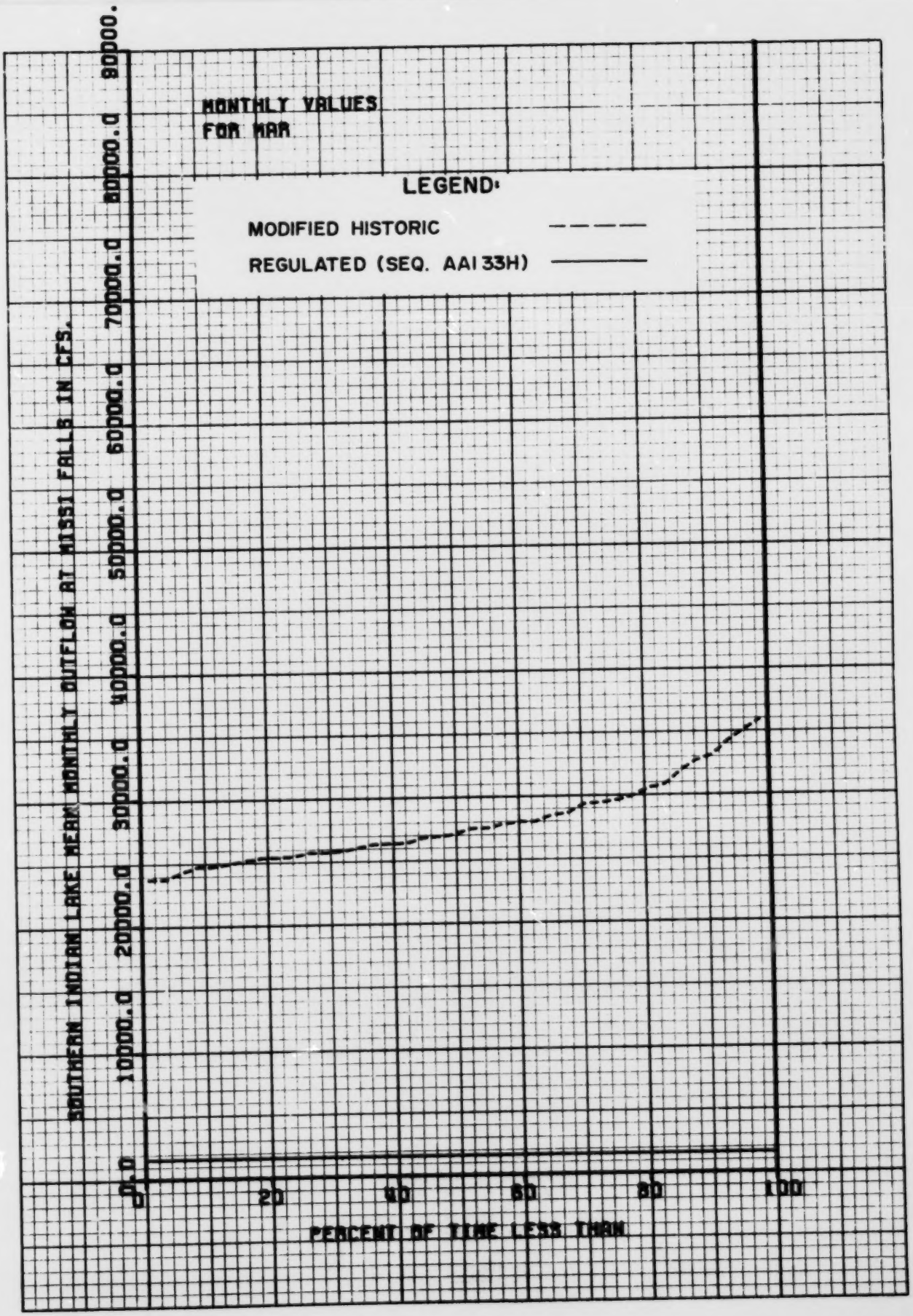
Range 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	64	18	75	17	86	14	95	0	10	49	16	4	19	19	24	35	1	33	33	51	41	38	49	33
5-10	0	13	0	6	0	1	3	0	6	0	10	0	9	19	3	18	5	33	5	5	2	10	2	13
10-20	0	5	0	2	0	0	2	0	16	0	43	0	0	28	2	18	0	26	2	0	0	8	0	2
20-30	0	0	0	0	0	0	0	0	15	0	17	0	0	5	0	0	0	0	2	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	2	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0

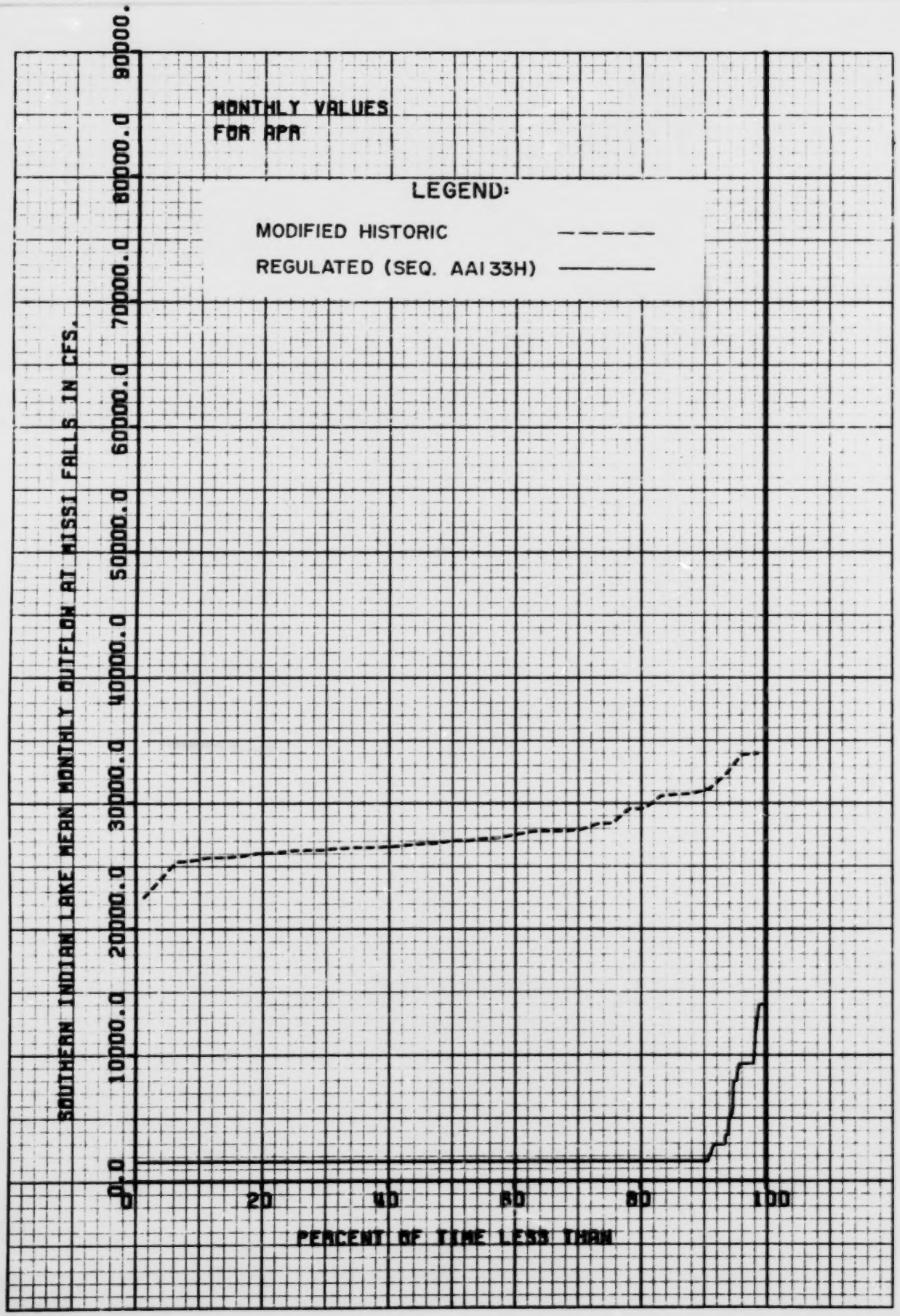
- FLOWS IN CFS -

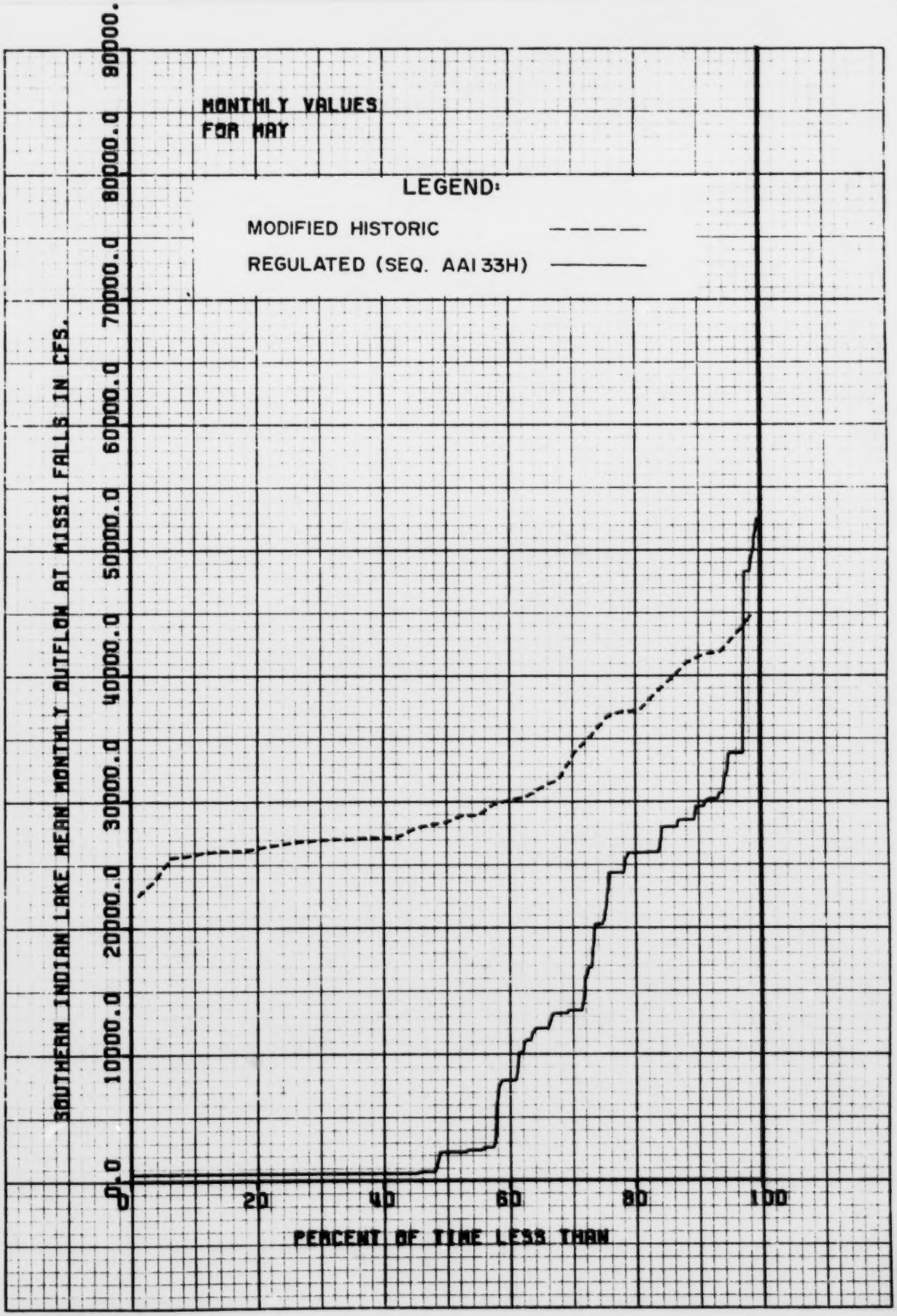
													ANNUAL
MINIMUM	1500	1500	1500	1500	500	500	500	500	500	500	1500	1500	500
AVERAGE	2824	1906	1500	2025	10162	25409	18940	15204	8061	8504	6704	5051	8857
MAXIMUM	14957	6509	1500	13987	52437	73789	49893	40428	32001	34968	29021	21430	73789

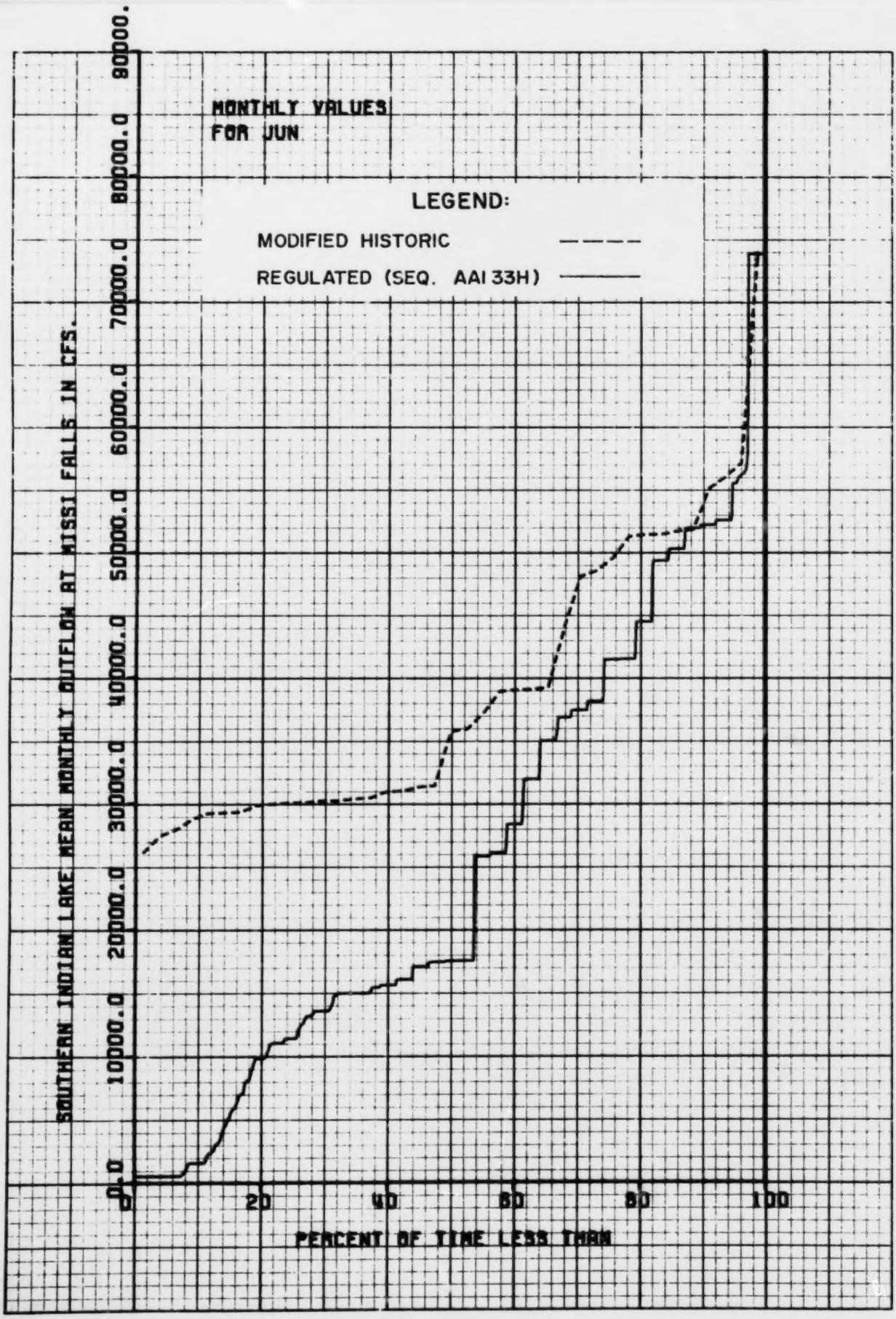

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

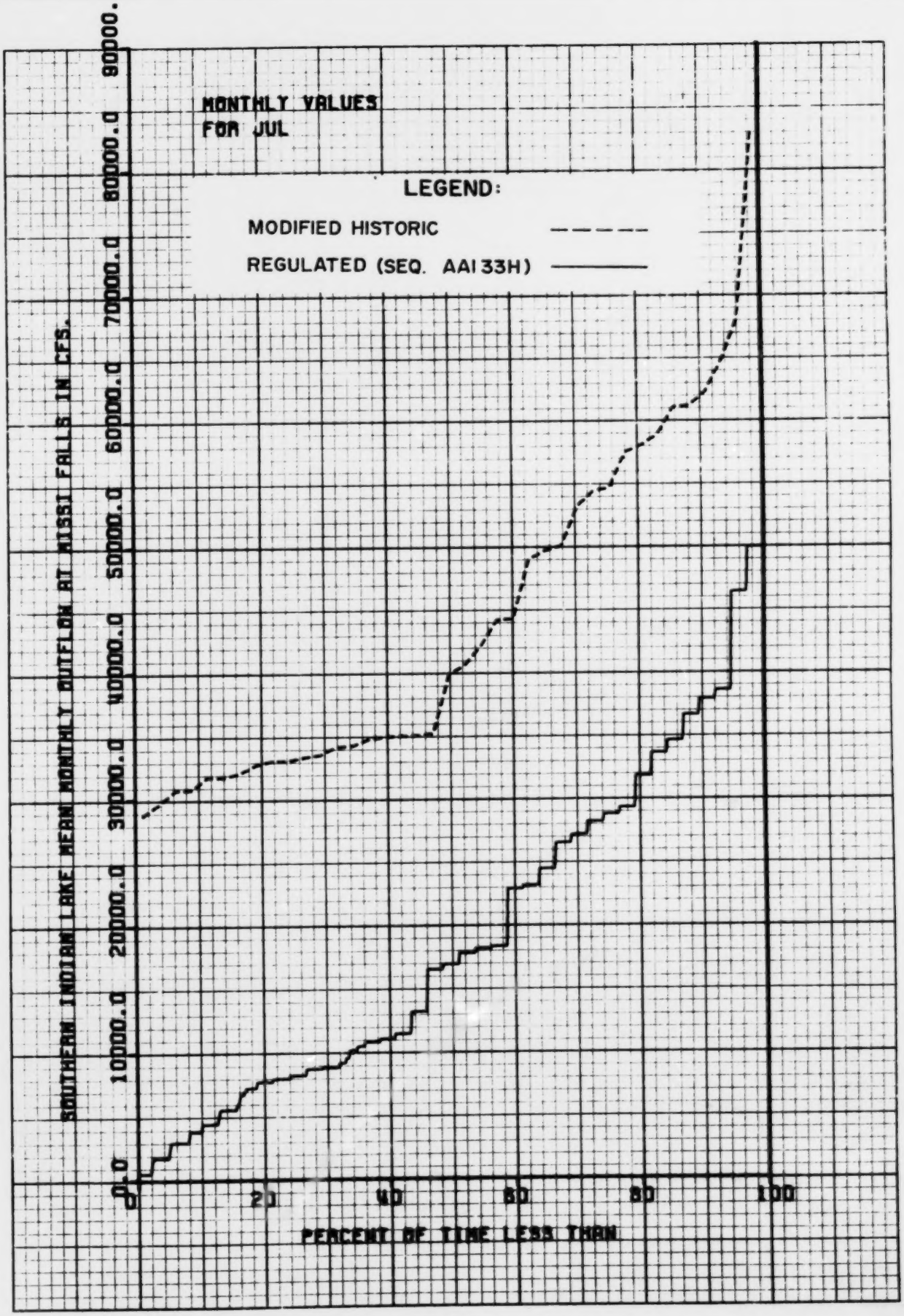

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

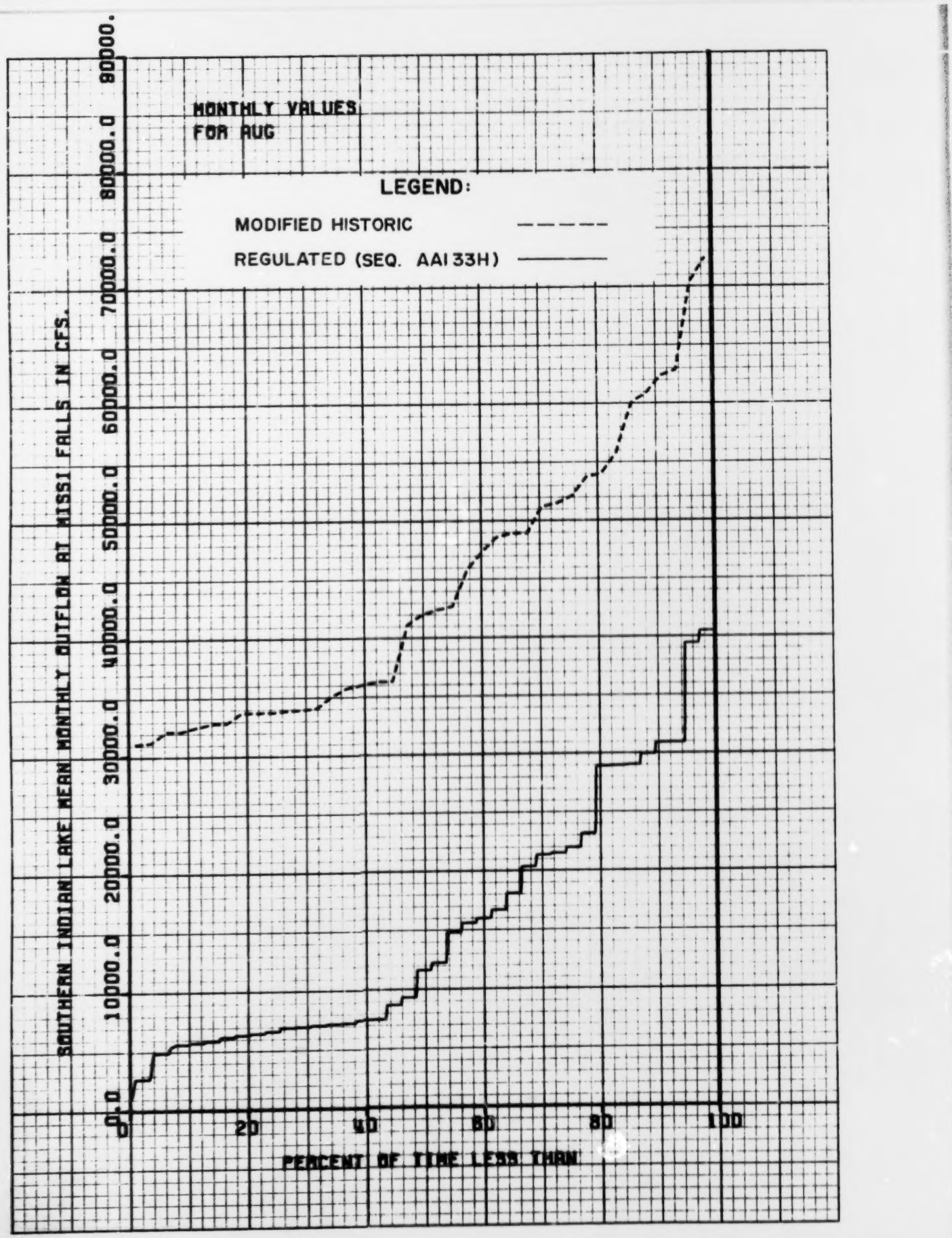

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

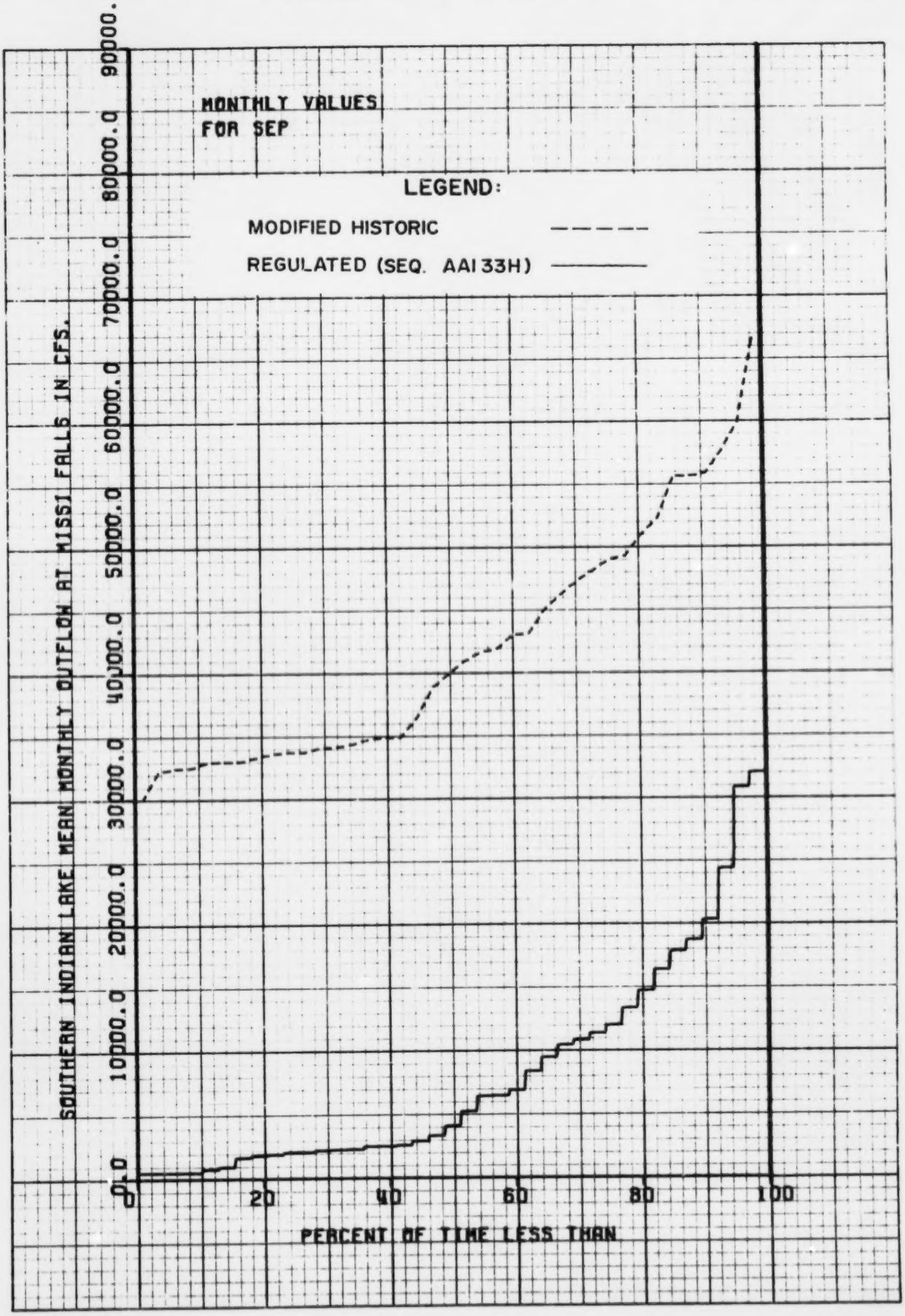

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

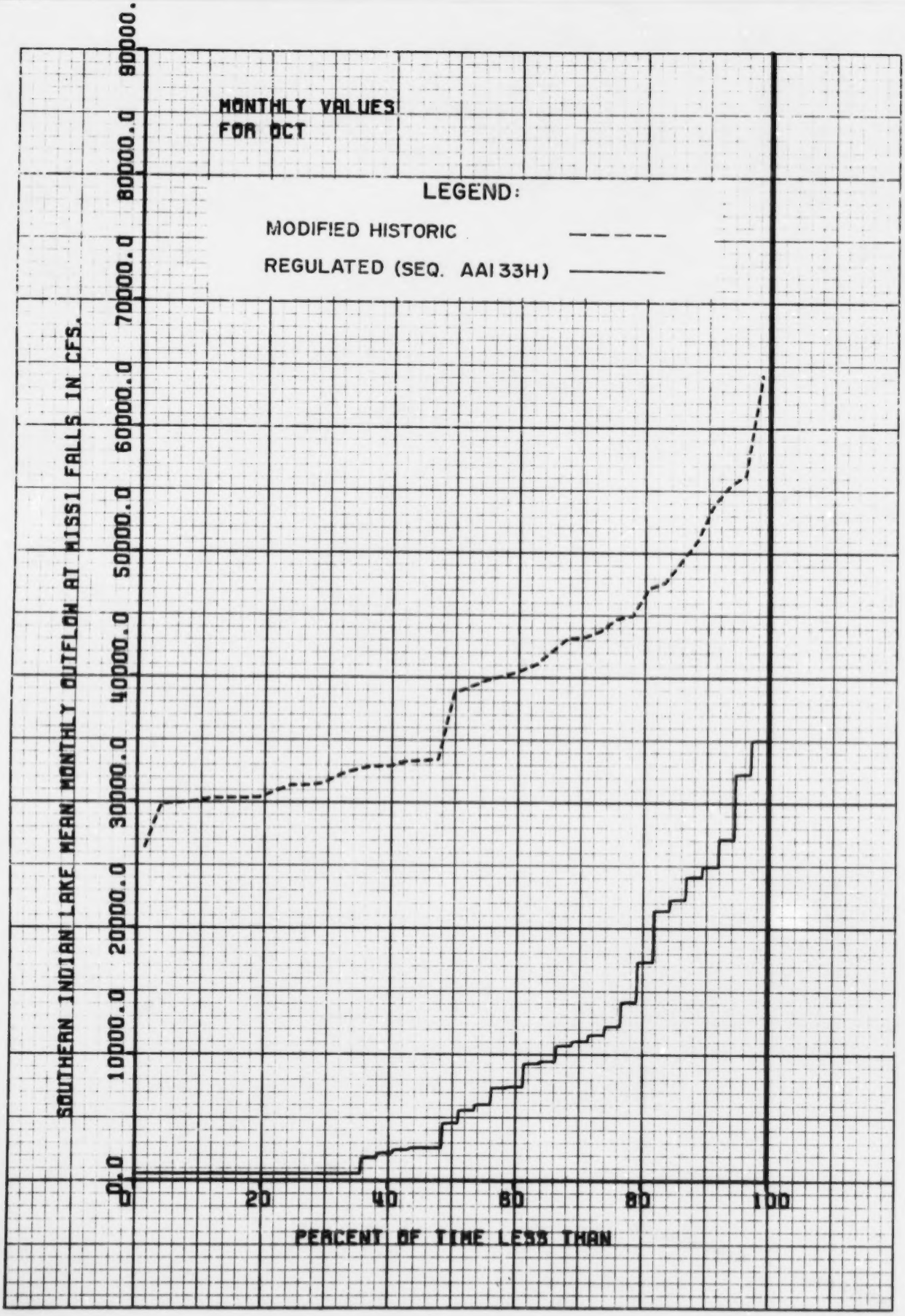

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

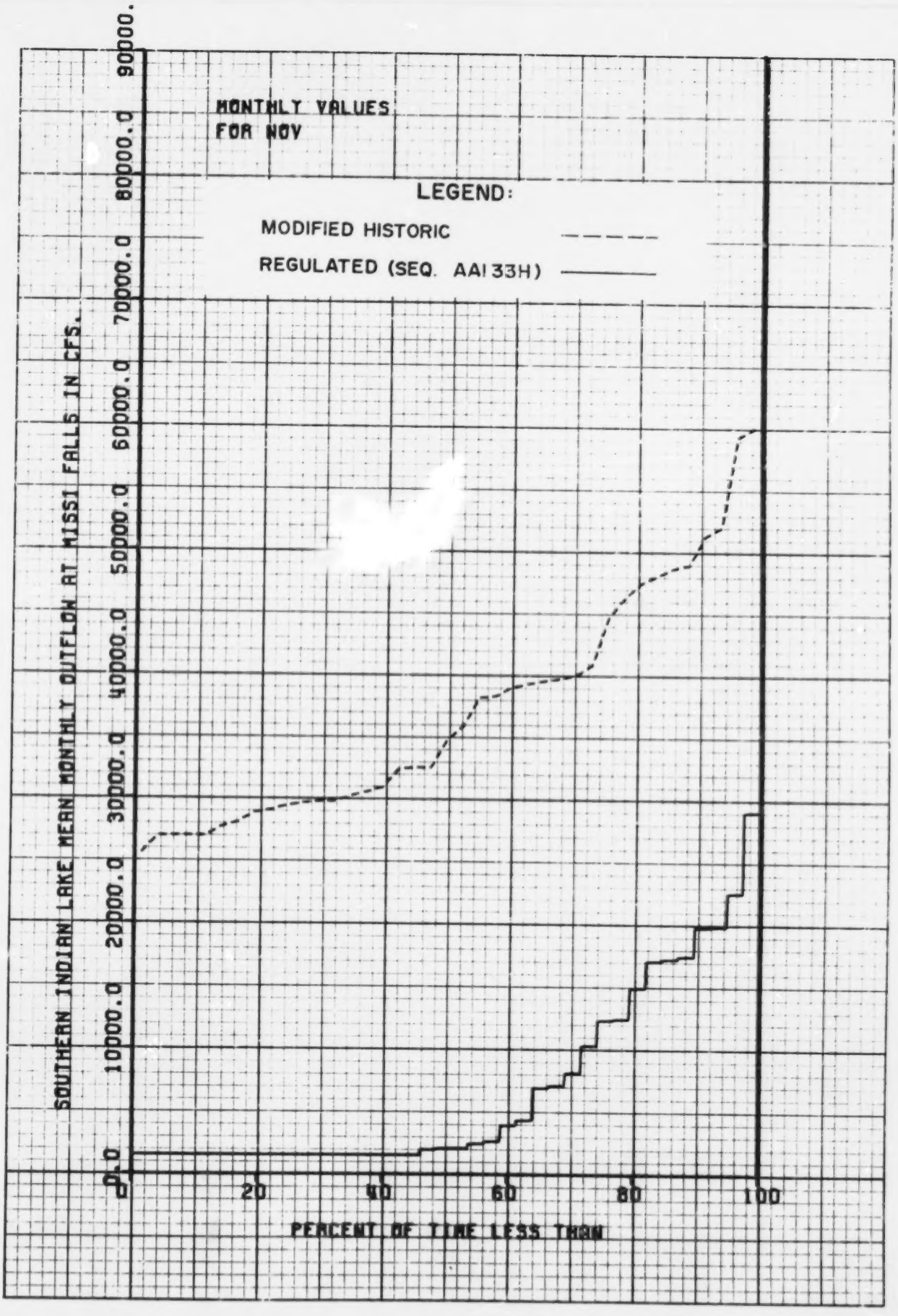

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

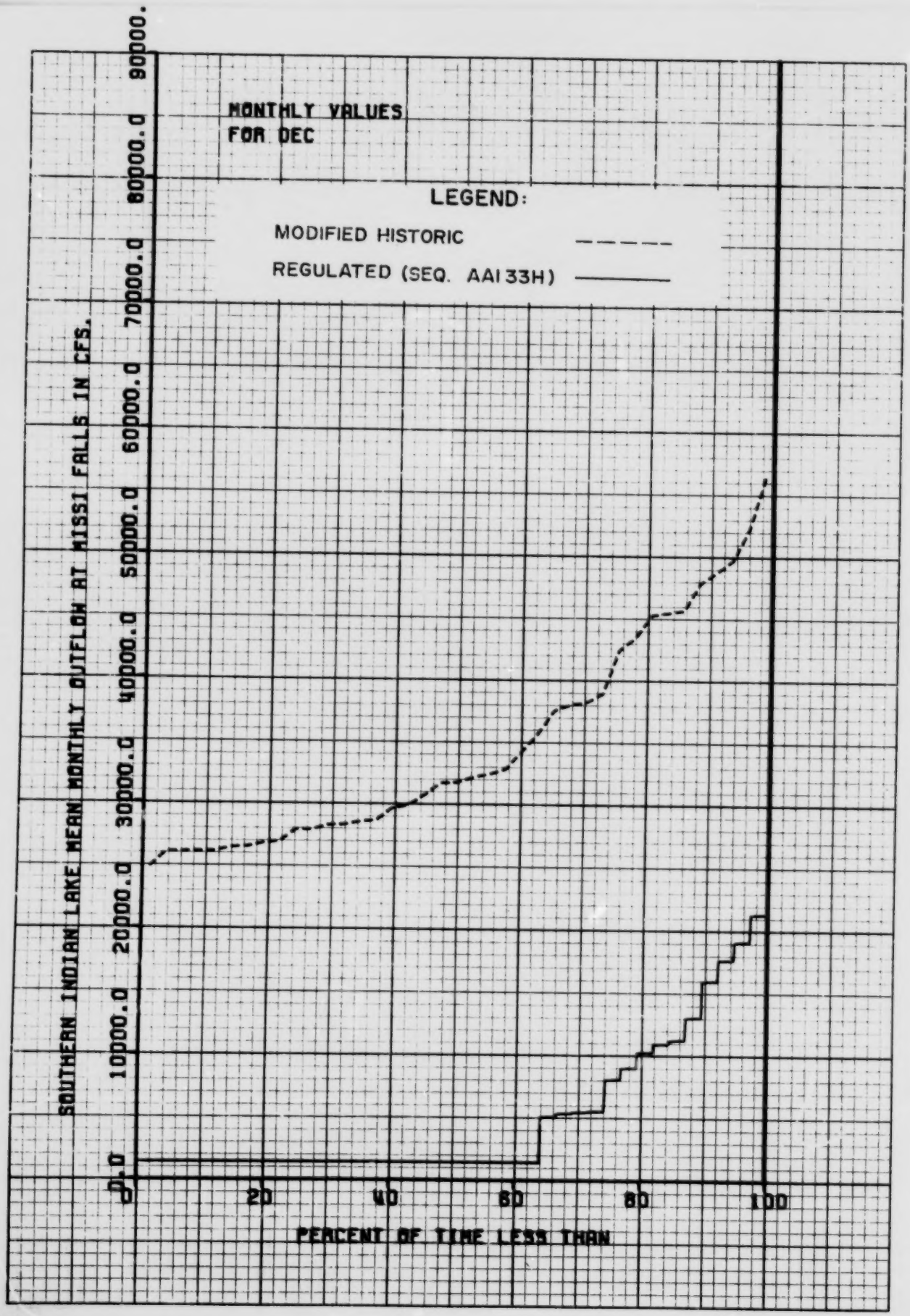

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHEAN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SOUTHERN INDIAN LAKE (MISSI FALLS) OUTFLOWS HYDROLOGIC PERIOD 1912 - 1967

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	0	62	0	98	57	43	52	48	80	7	7	0	59	5	4	64	4	39	32	61	27	71	11	73
5-10	0	36	0	2	0	0	0	0	13	0	20	0	20	0	0	29	2	50	2	5	0	2	0	16
10-20	0	2	0	0	0	0	0	0	0	0	66	0	16	0	0	4	0	5	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

													ANNUAL
MINIMUM	18408	17636	18018	16991	18144	20792	21742	21485	18002	19324	19927	20530	16991
AVERAGE	29385	27525	27540	27588	30358	42297	47938	43663	38362	37481	36455	34284	35240
MAXIMUM	38603	34902	34493	35841	40038	62325	77100	69636	62180	57476	53144	47508	77100

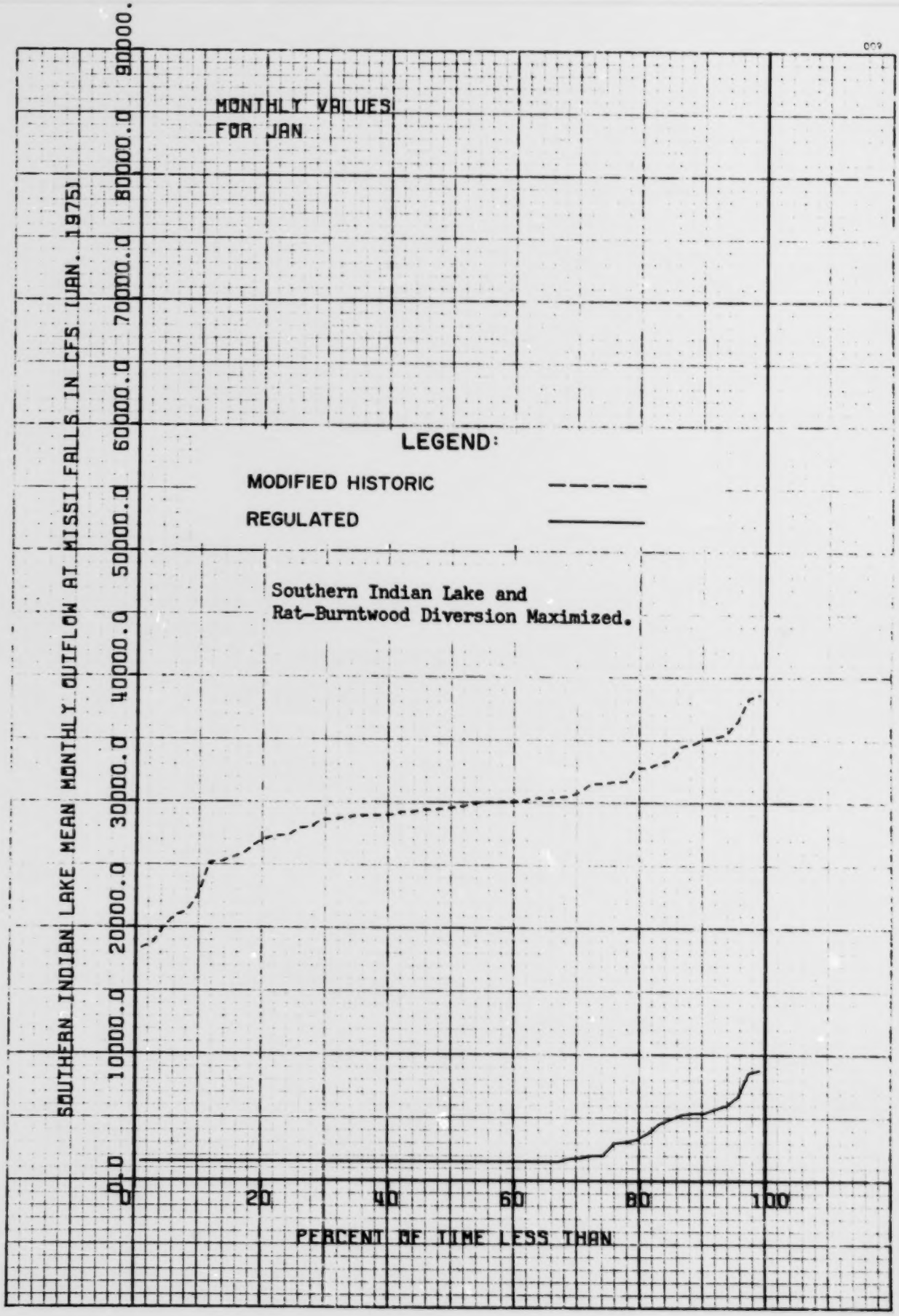
POST DIVERSION FLOWS

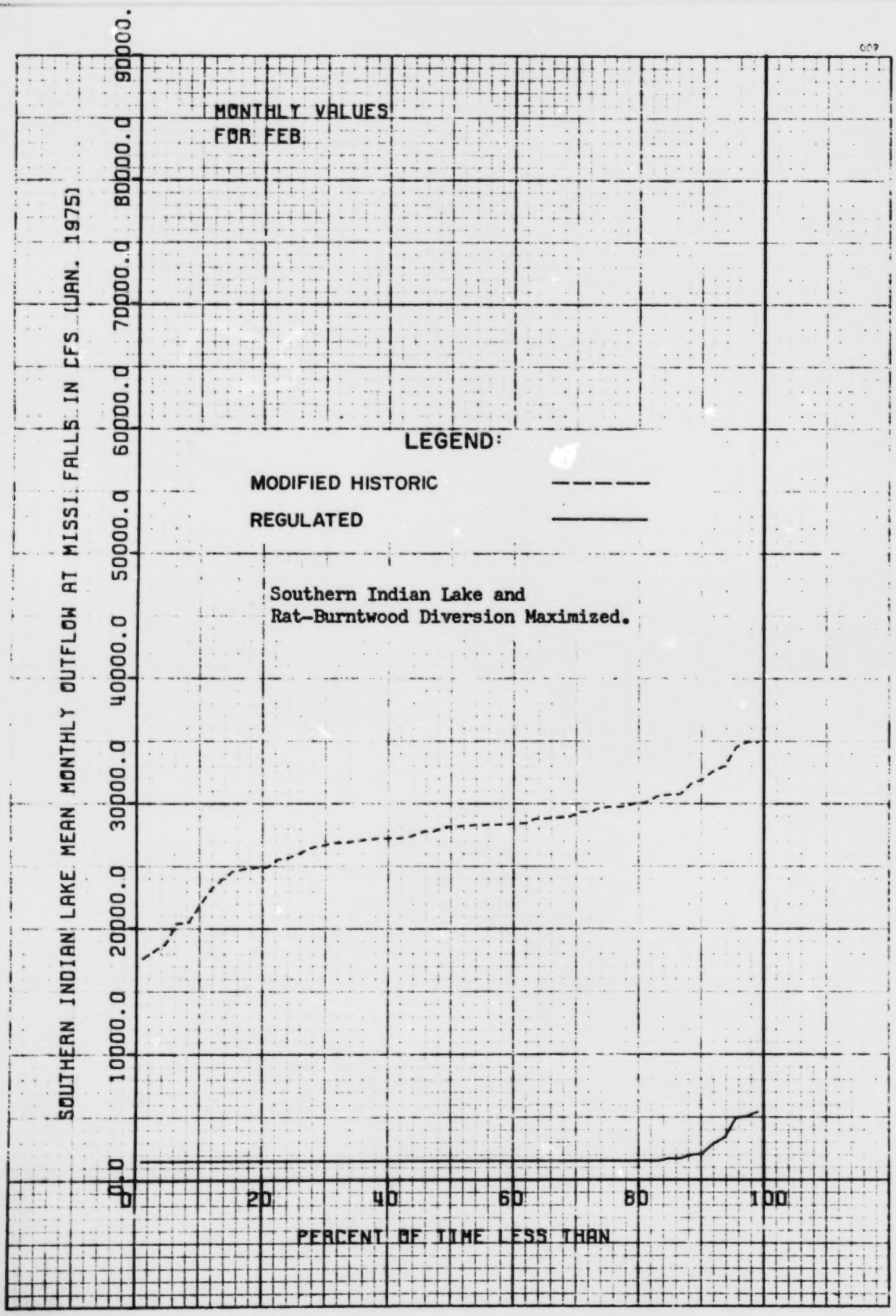
- FLUCTUATIONS IN PERCENT -

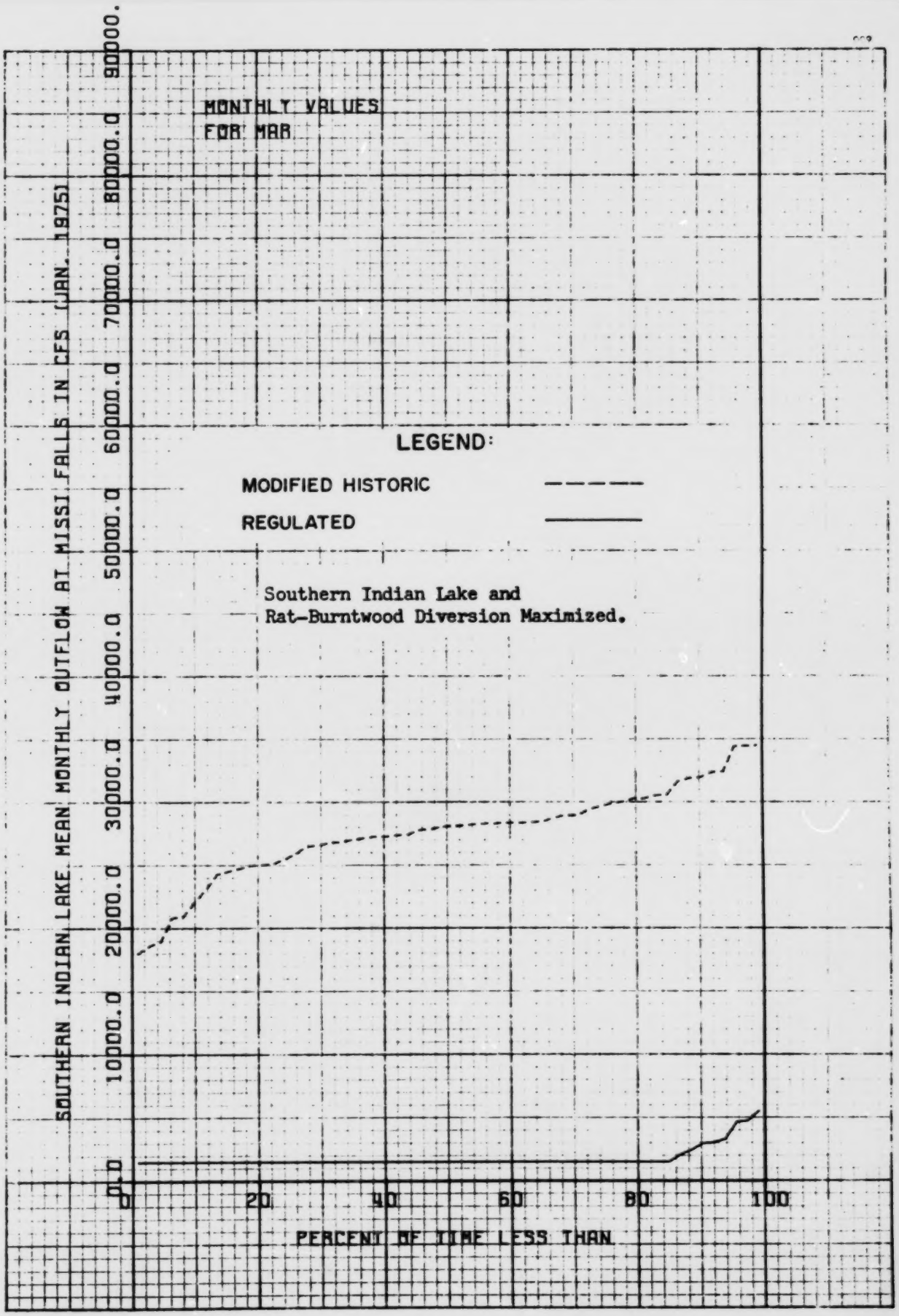
Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	18	56	68	32	89	11	100	0	5	77	23	0	39	4	20	14	18	25	27	61	29	68	18	63
5-10	0	20	0	0	0	0	0	0	16	0	18	0	32	2	2	54	2	48	2	11	0	4	4	16
10-20	0	5	0	0	0	0	0	0	2	0	43	0	20	0	0	11	0	7	0	0	0	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	14	0	4	0	0	0	0	0	0	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

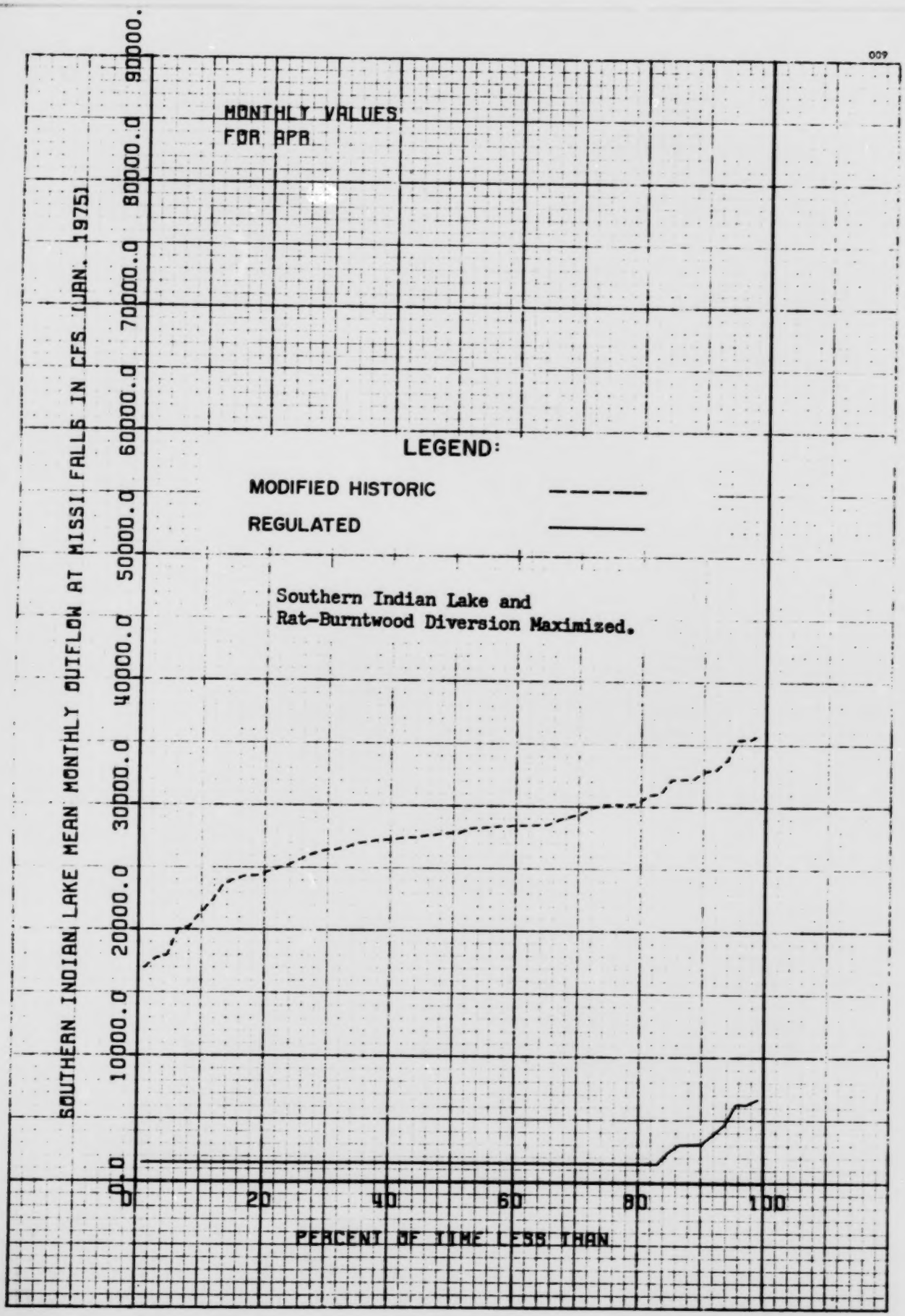
- FLOWS IN CFS -

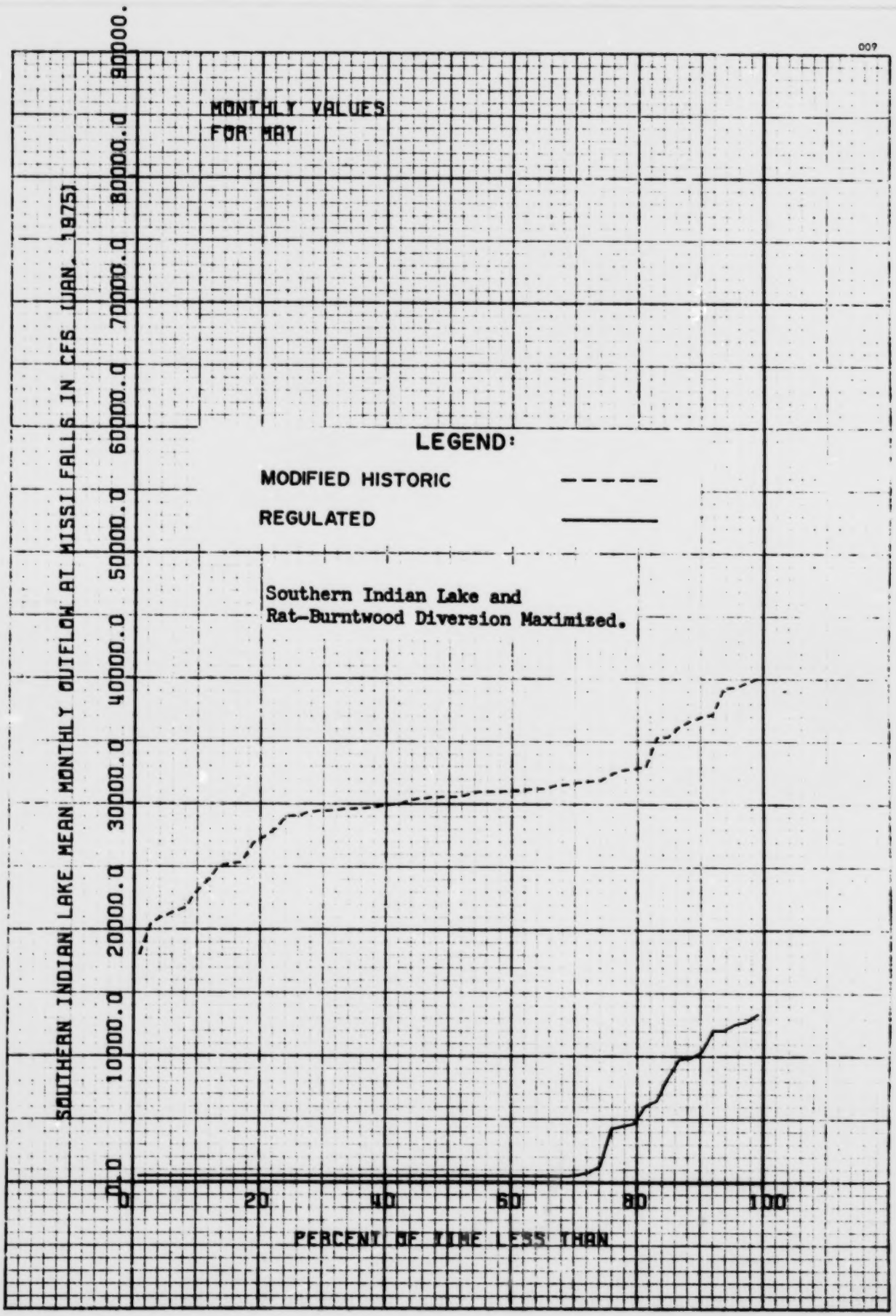
													ANNUAL
MINIMUM	1500	1500	1500	1500	500	500	500	500	500	500	1500	1500	500
AVERAGE	2485	1782	1803	1968	2674	13901	20323	15326	10546	9214	8108	6019	7846
MAXIMUM	8800	5444	5572	6731	13400	37898	49697	40898	36398	28599	23999	18000	49697

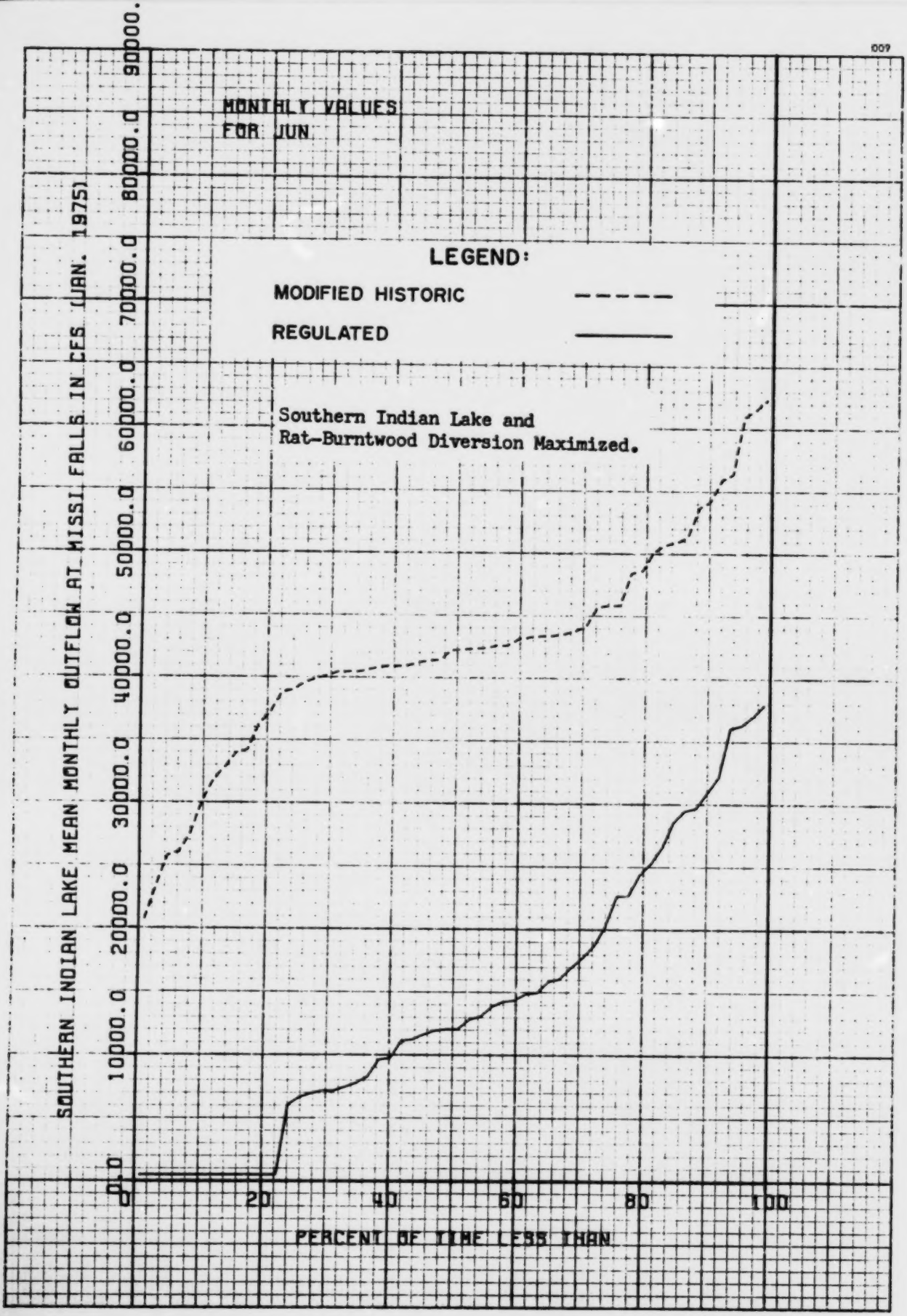

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

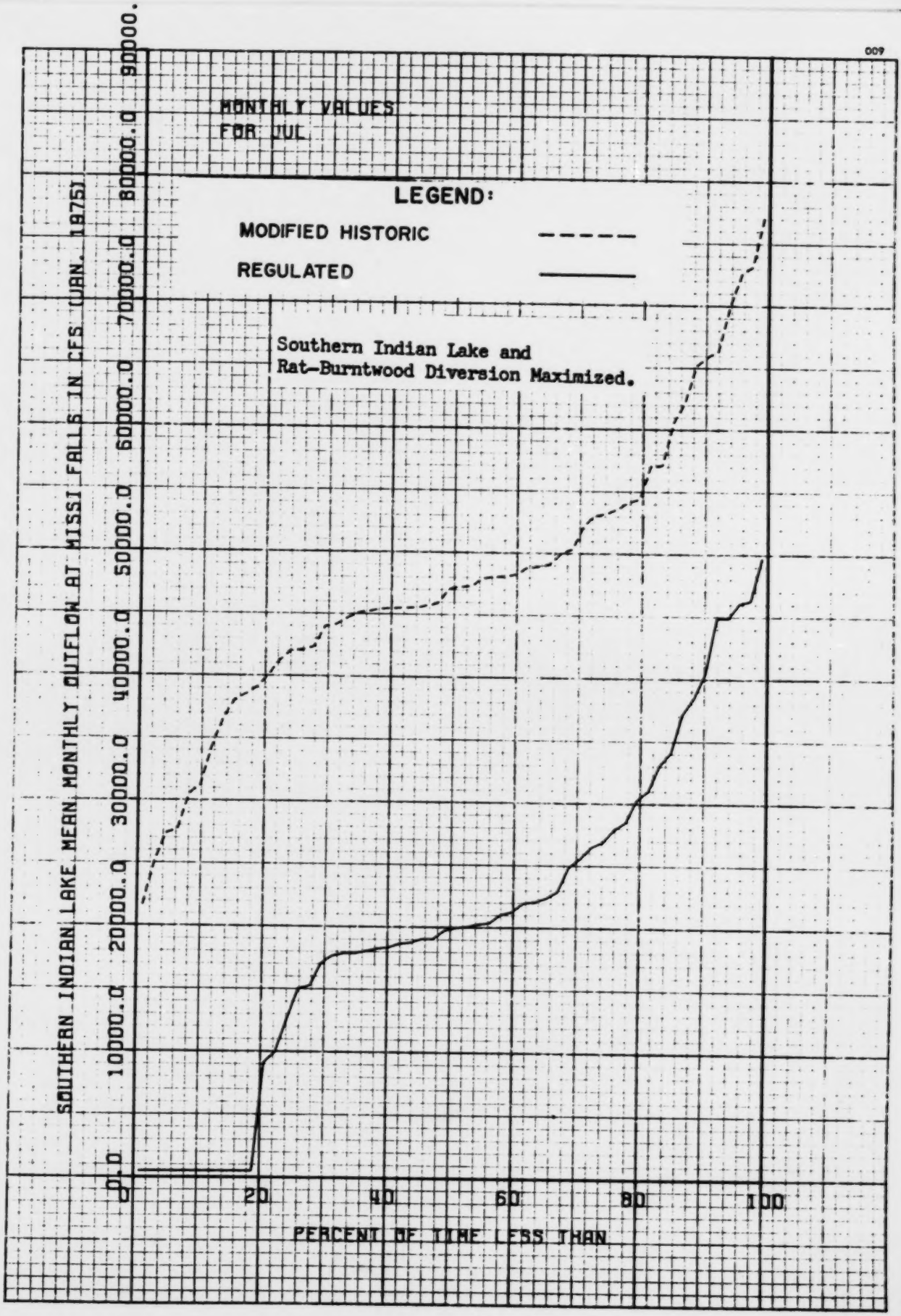

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

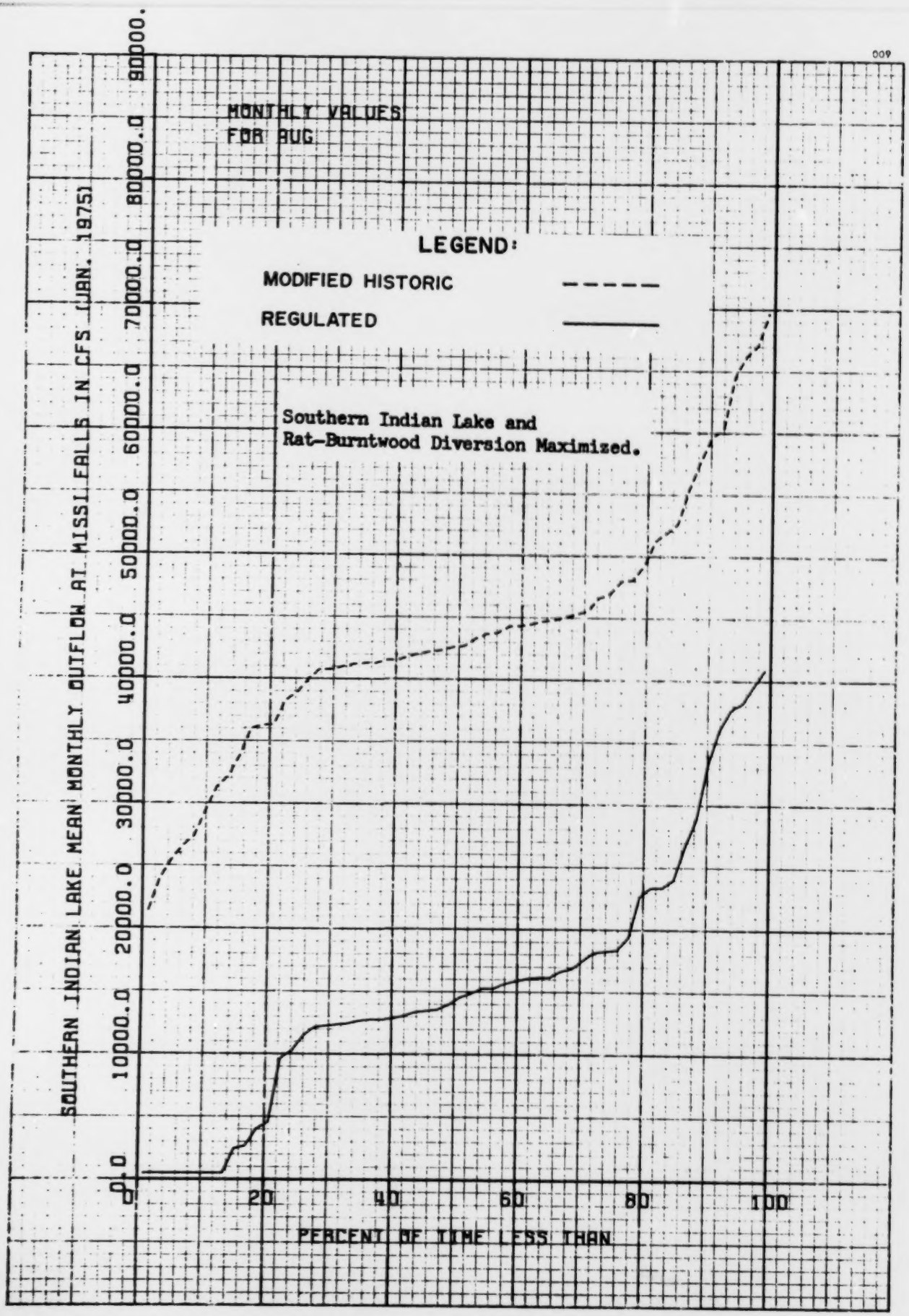

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

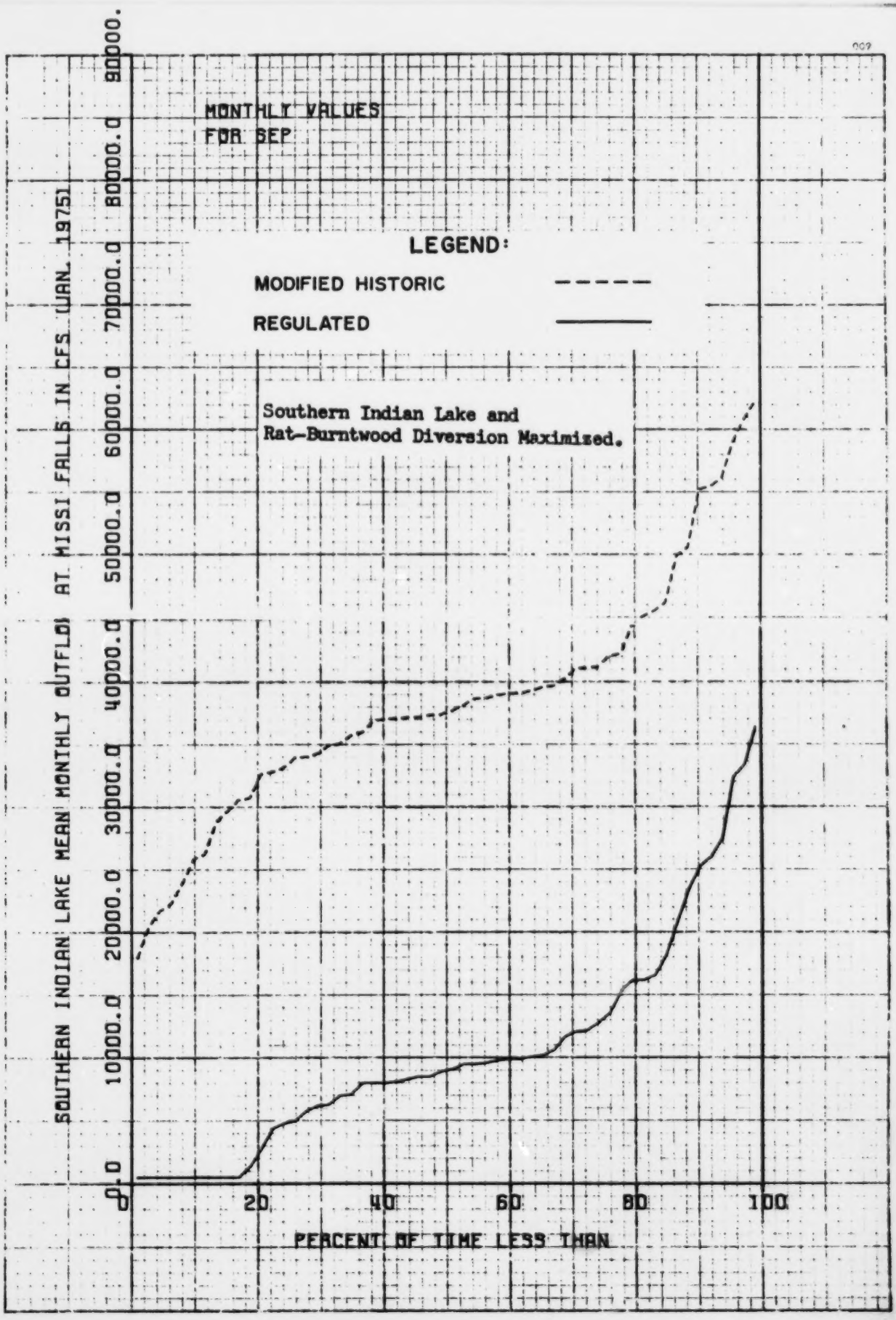

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG.
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
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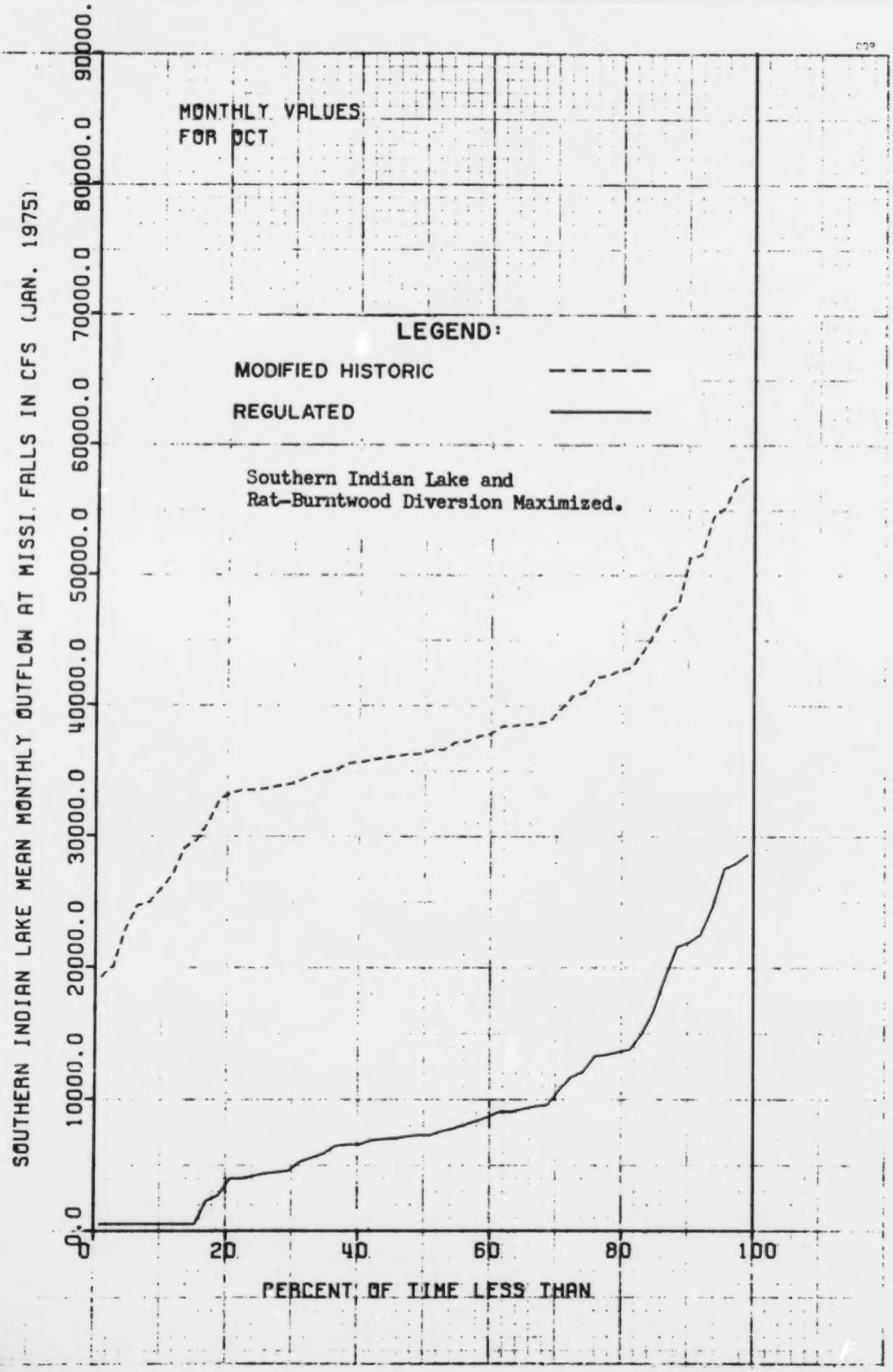
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
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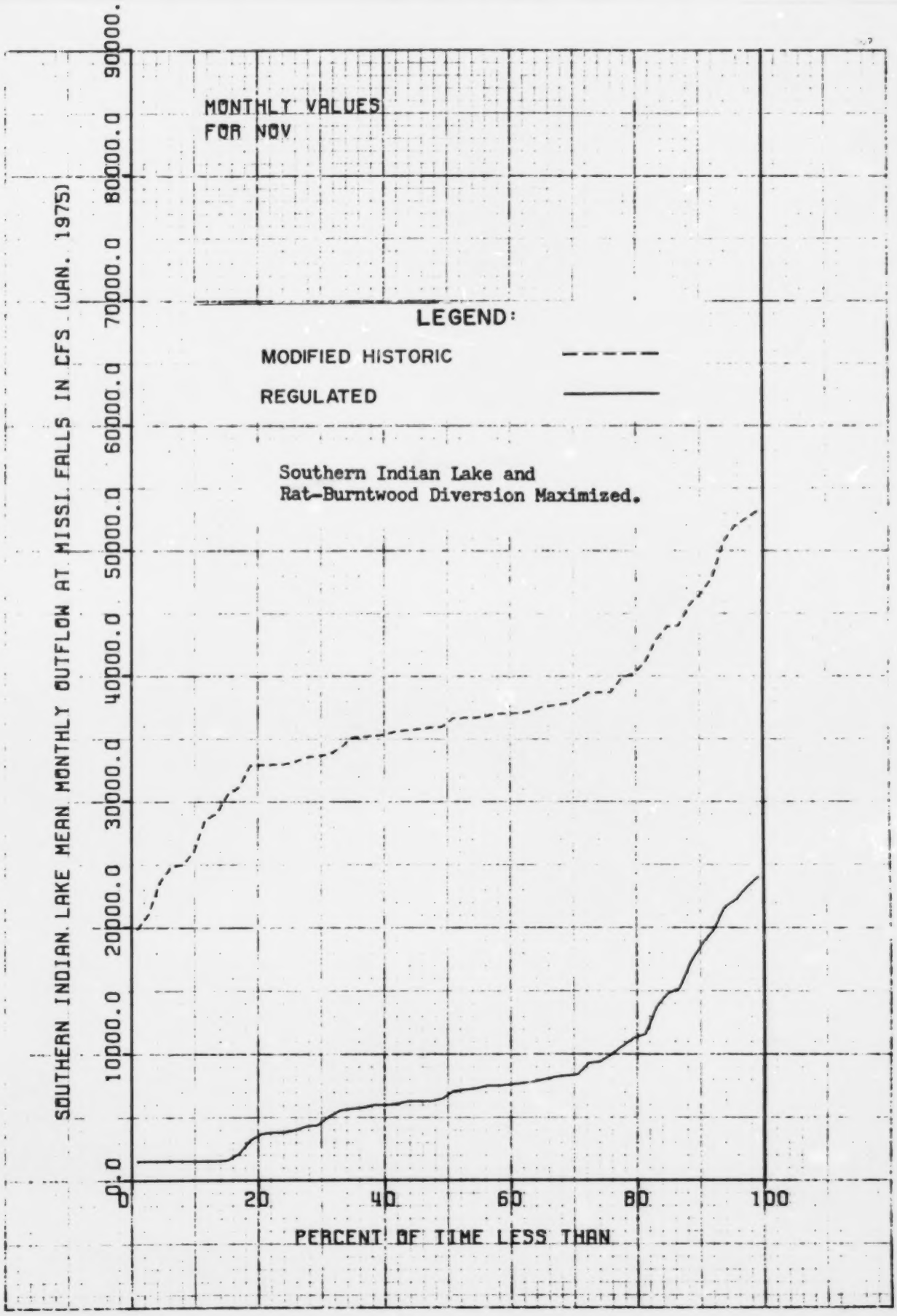
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
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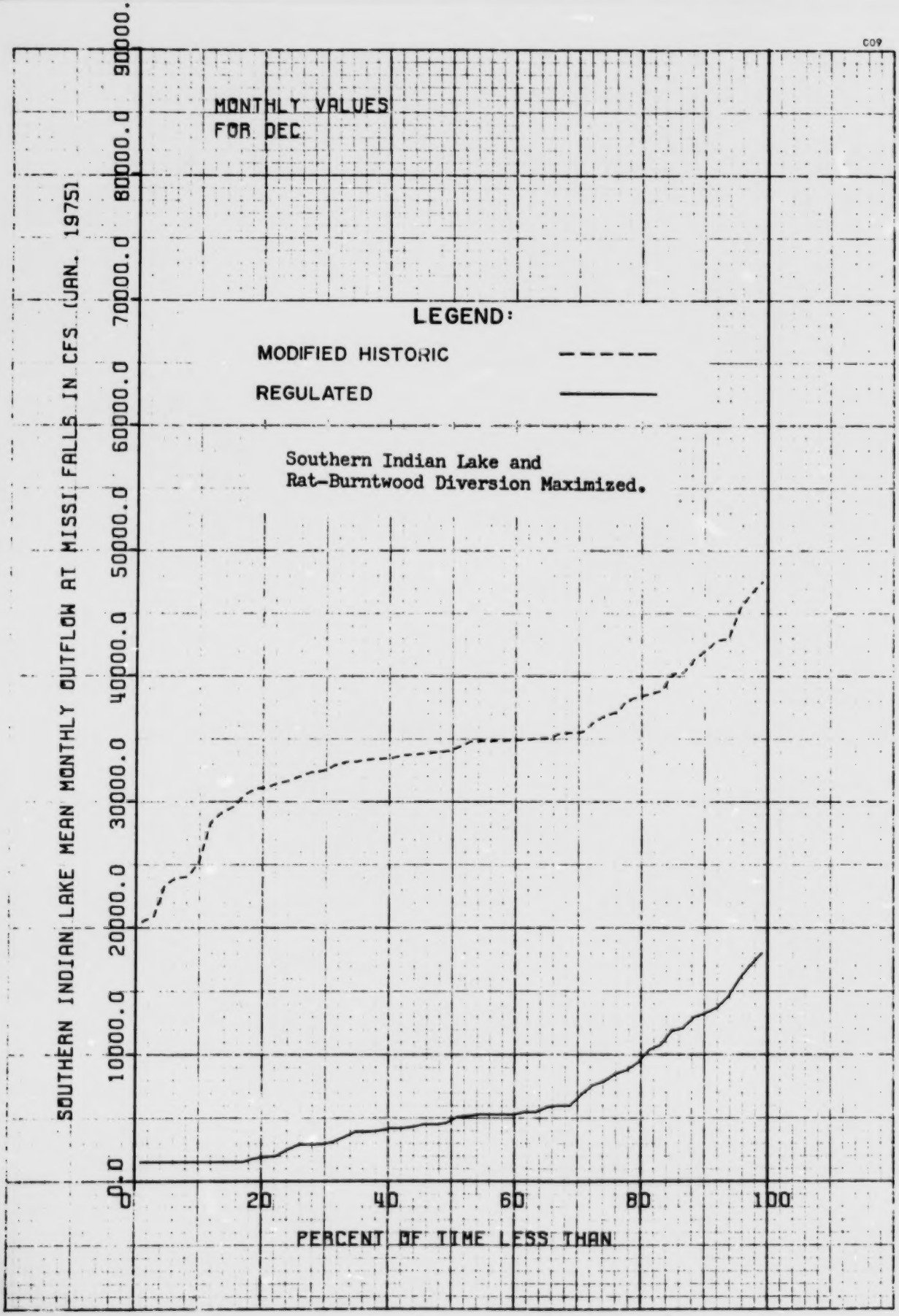
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED
Southern Indian Lake and
Rat-Burntwood Diversion Maximized.
SOUTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW AT MISSI FALLS IN CFS (JAN. 1975)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SOUTHERN INDIAN LAKE
INFLOWS

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SOUTHERN INDIAN LAKE INFLOWS HYDROLOGIC PERIOD 1912 - 1967

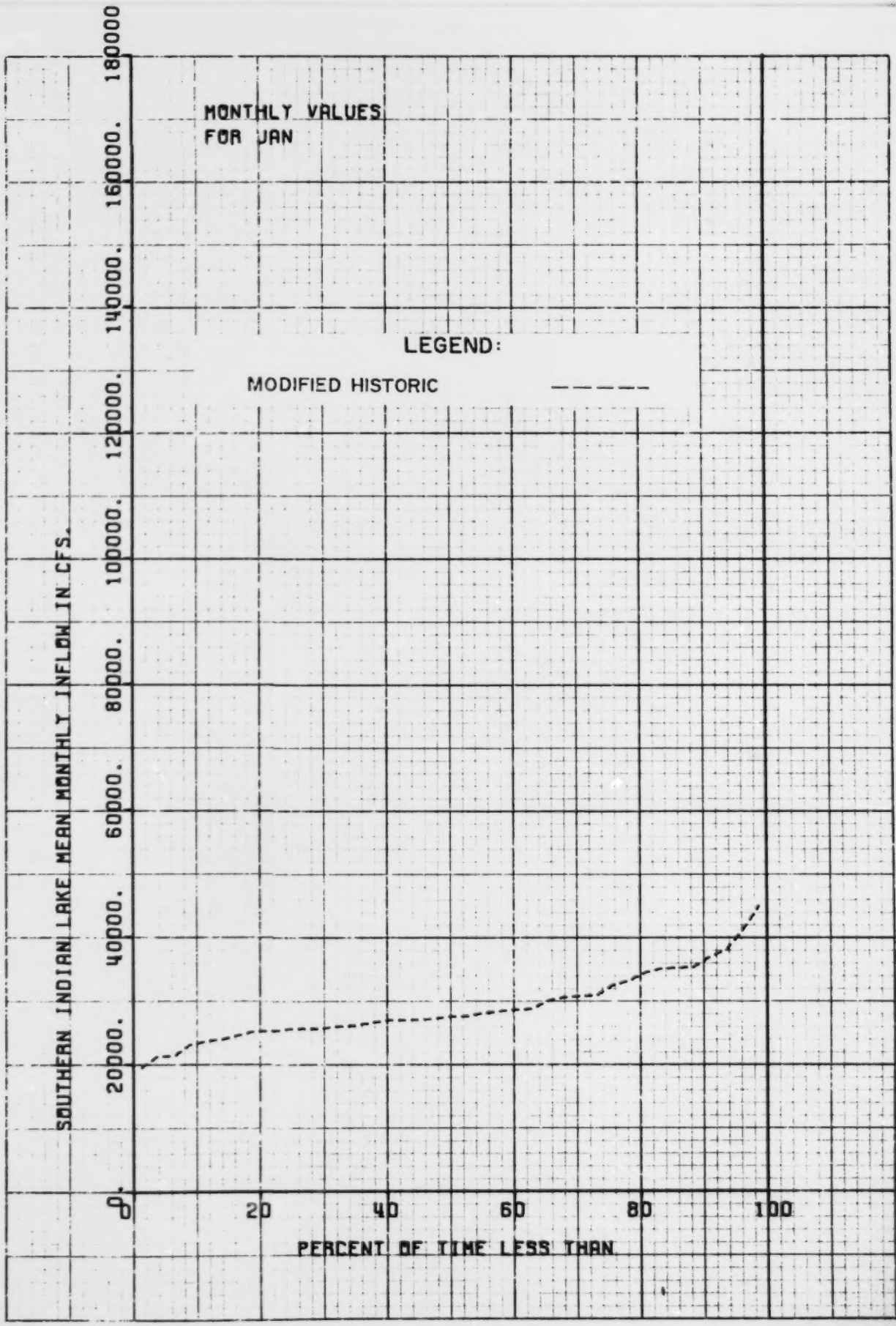
MODIFIED HISTORIC INFLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	32	47	23	59	59	28	36	44	41	10	8	3	23	23	33	28	0	49	31	36	36	33	13	46
5-10	0	13	3	10	0	13	10	3	8	0	51	5	5	28	15	10	3	28	8	21	5	21	3	36
10-20	0	8	0	5	0	0	8	0	21	0	23	0	0	15	3	10	3	15	3	0	0	5	0	3
20-30	0	0	0	0	0	0	0	0	15	0	3	0	0	3	0	0	0	0	3	0	0	0	0	0
30-40	0	0	0	0	0	0	0	0	3	0	3	0	0	3	0	0	0	3	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

													ANNUAL
MINIMUM	19566	22096	21500	18750	22424	24800	27486	32668	22875	22806	22325	21384	18750
AVERAGE	28982	26847	26848	28269	38608	49705	44596	43744	37378	36774	35090	31349	35682
MAXIMUM	44957	35250	31125	43987	80452	96670	75766	69262	62001	64968	59021	51430	96670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FOR JAN
LEGEND:
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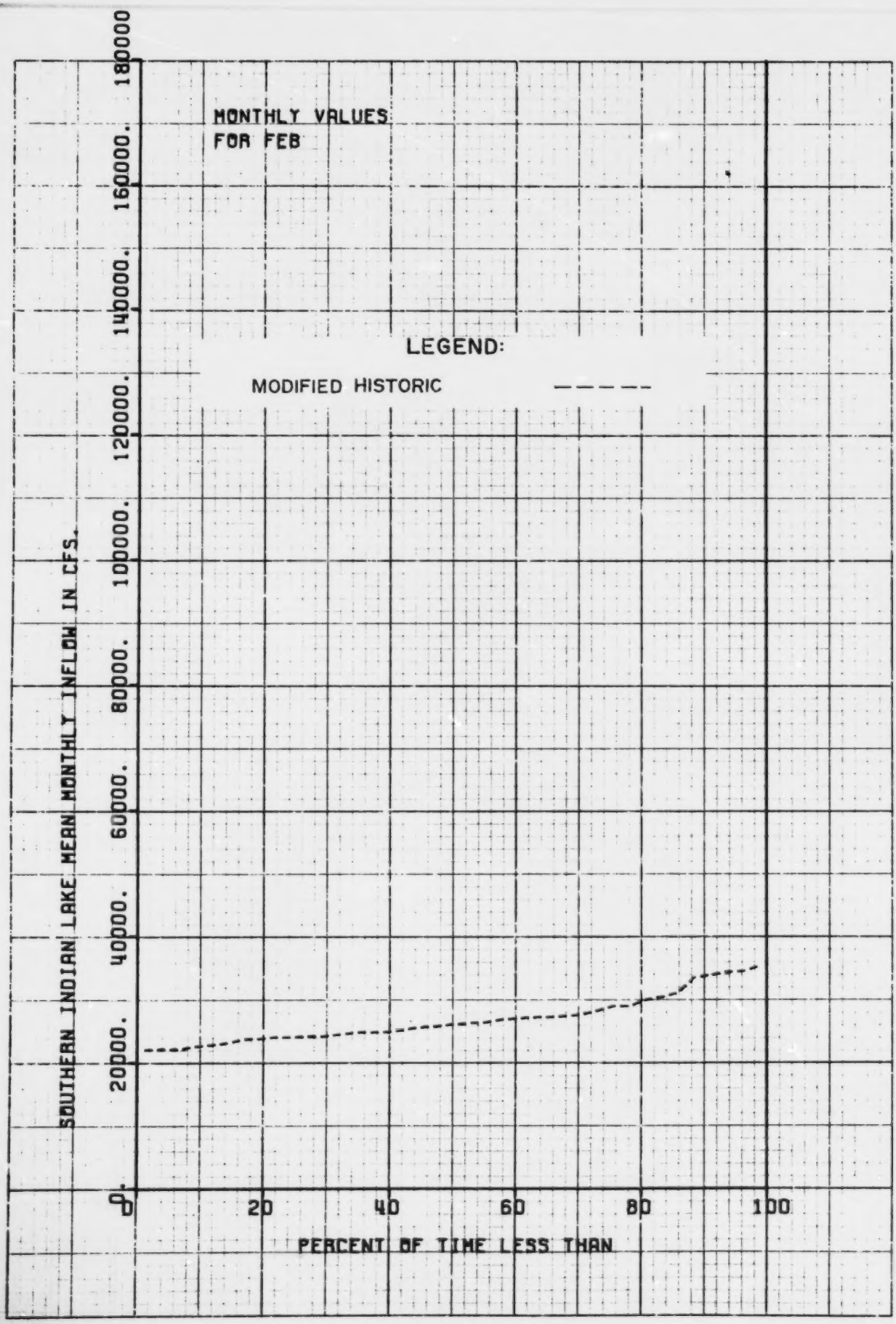
PERCENT OF TIME LESS THAN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LEGEND:
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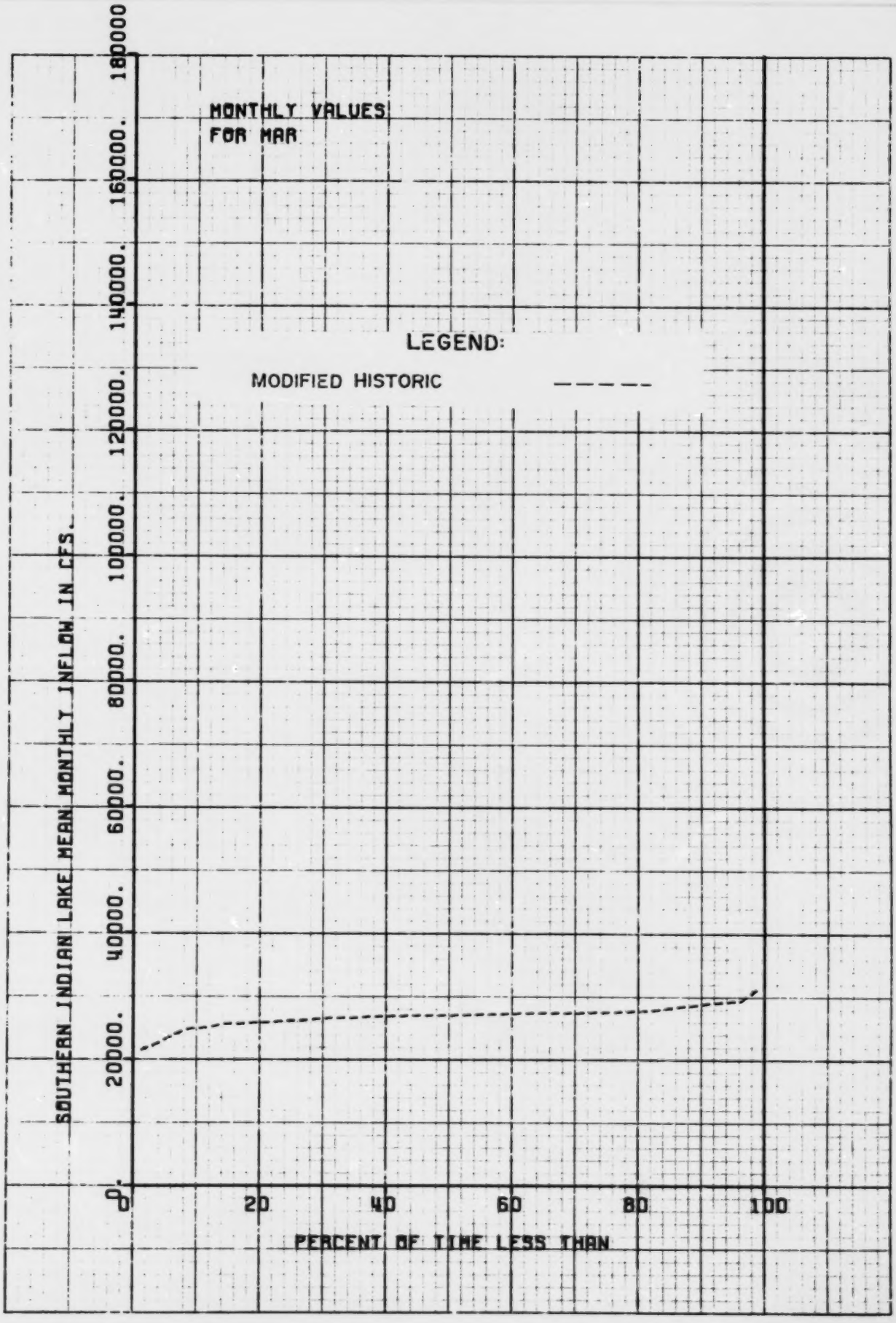
PERCENT OF TIME LESS THAN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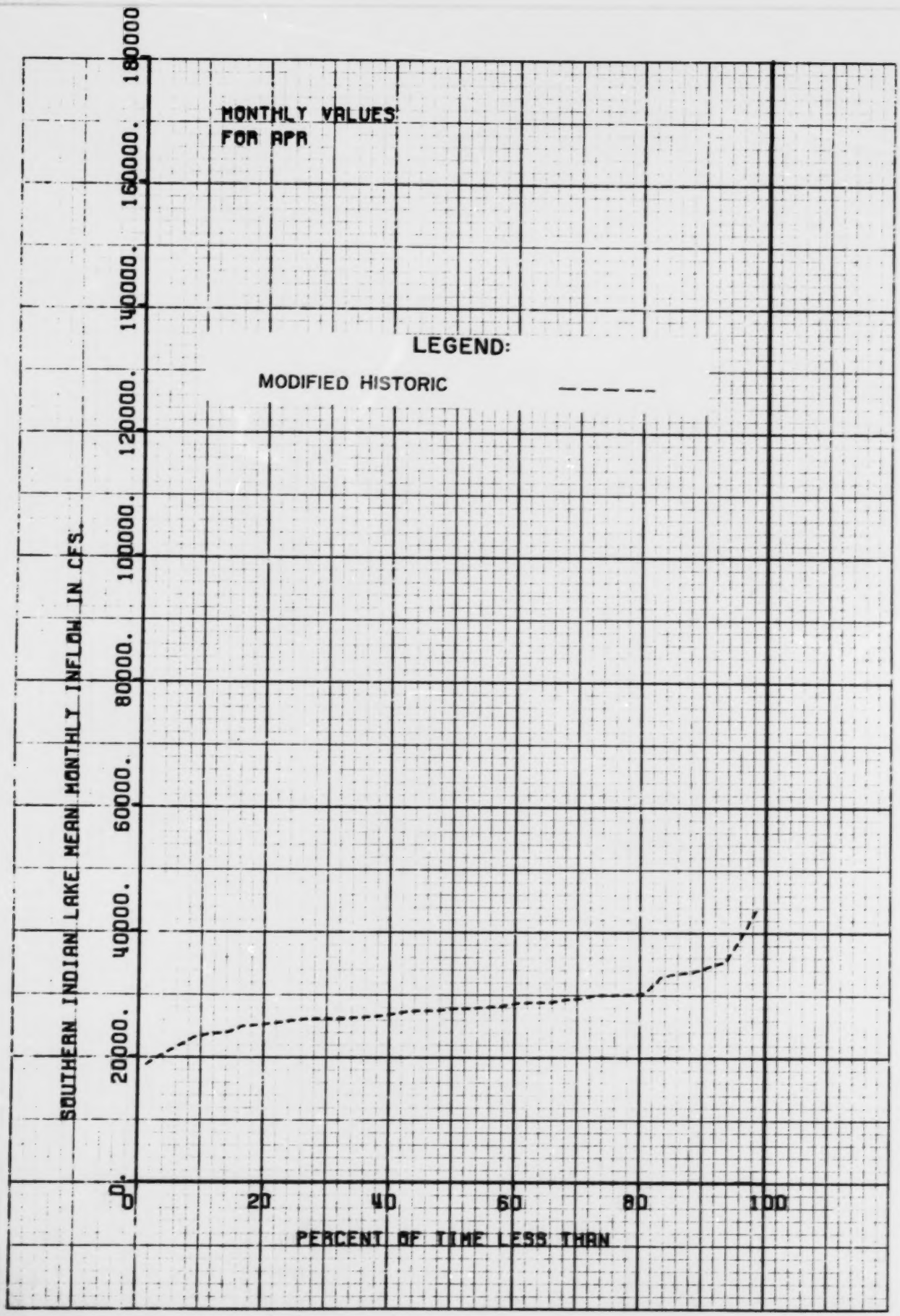
PERCENT OF TIME LESS THAN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LEGEND:
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SOUTHERN INDIANA LAKE MEAN MONTHLY INFLOW IN CFS.
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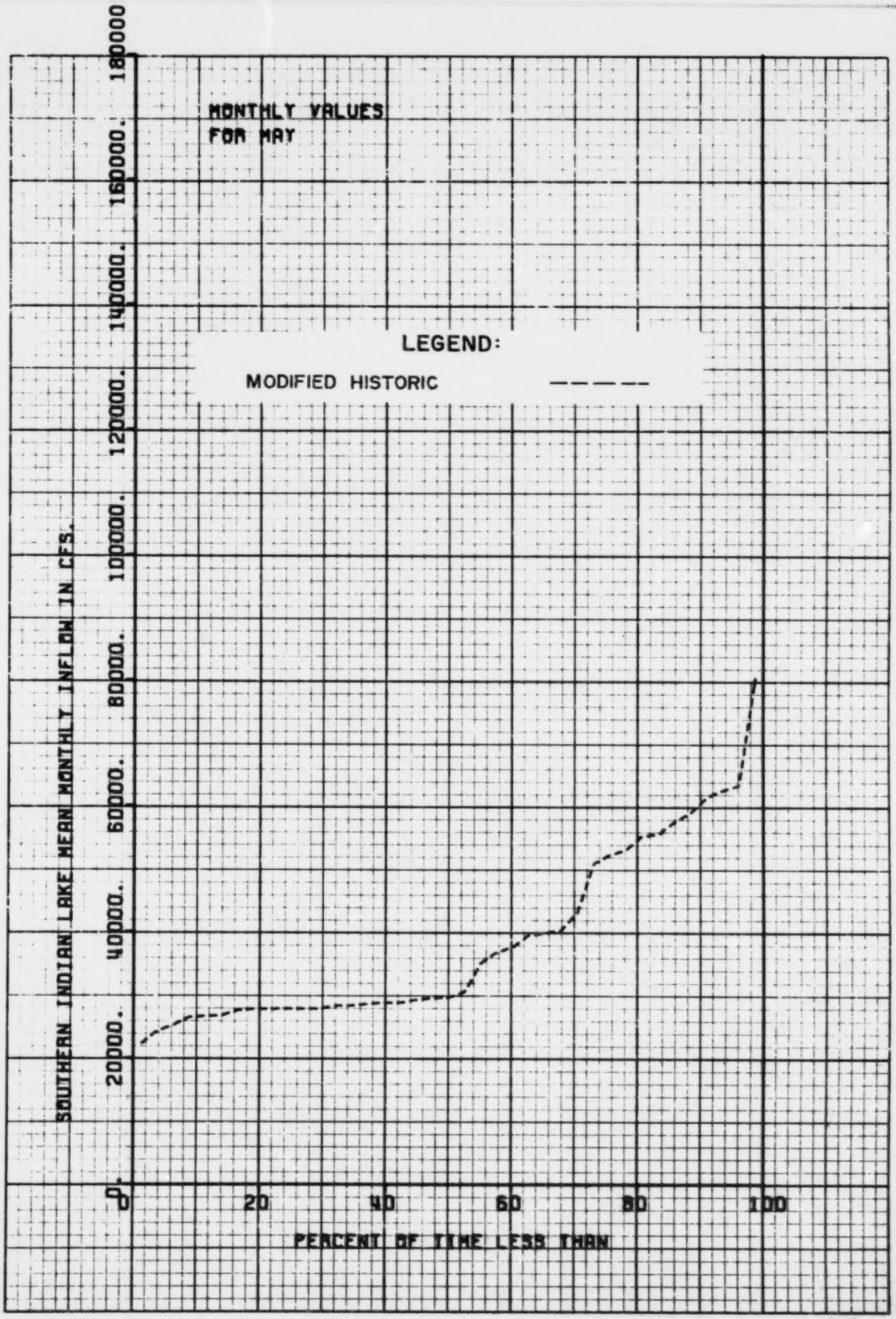
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
SOUTHEAN INDIAN LAKE MEAN MONTHLY INFLOW IN CFS.
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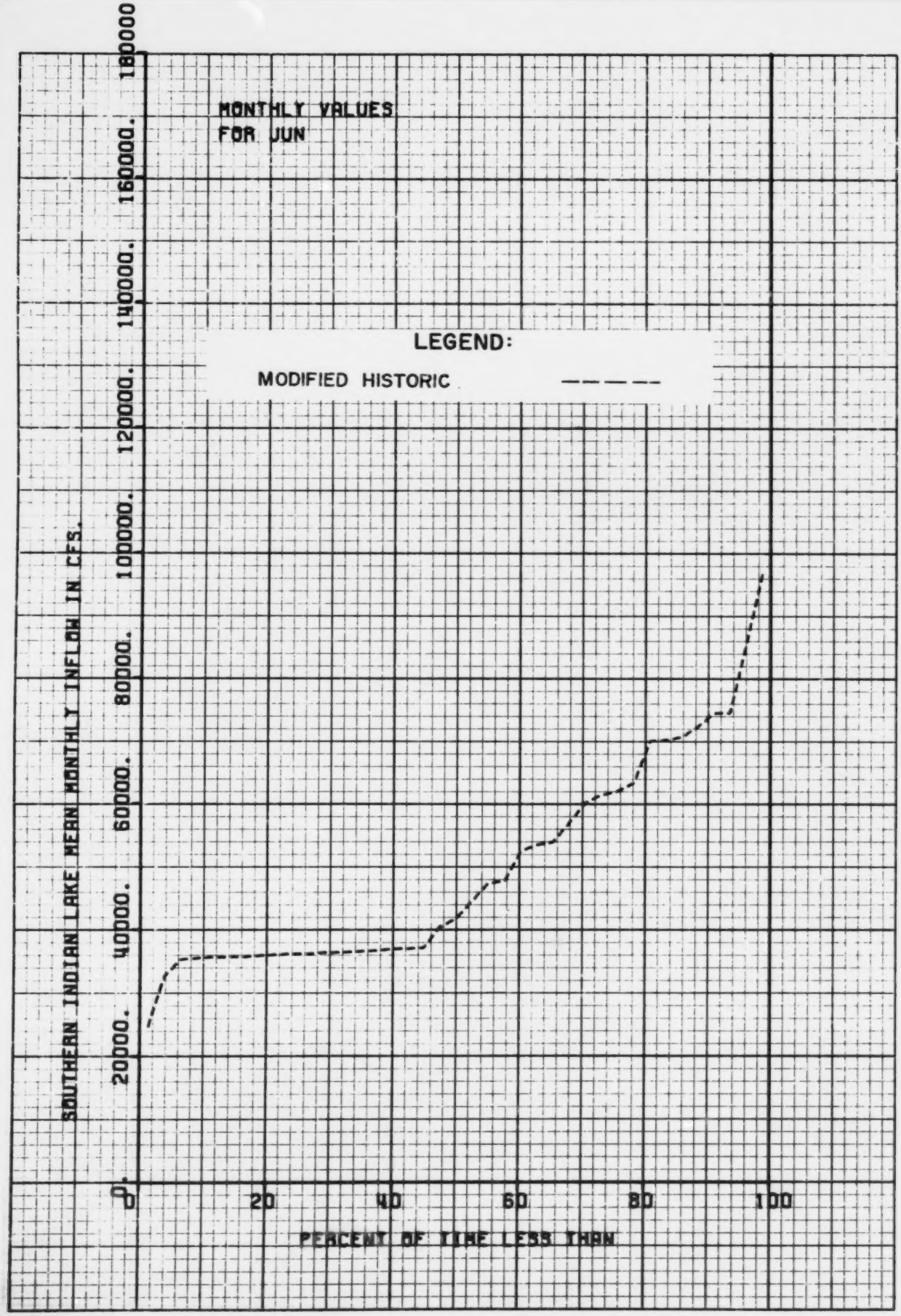
PERCENT OF TIME LESS THAN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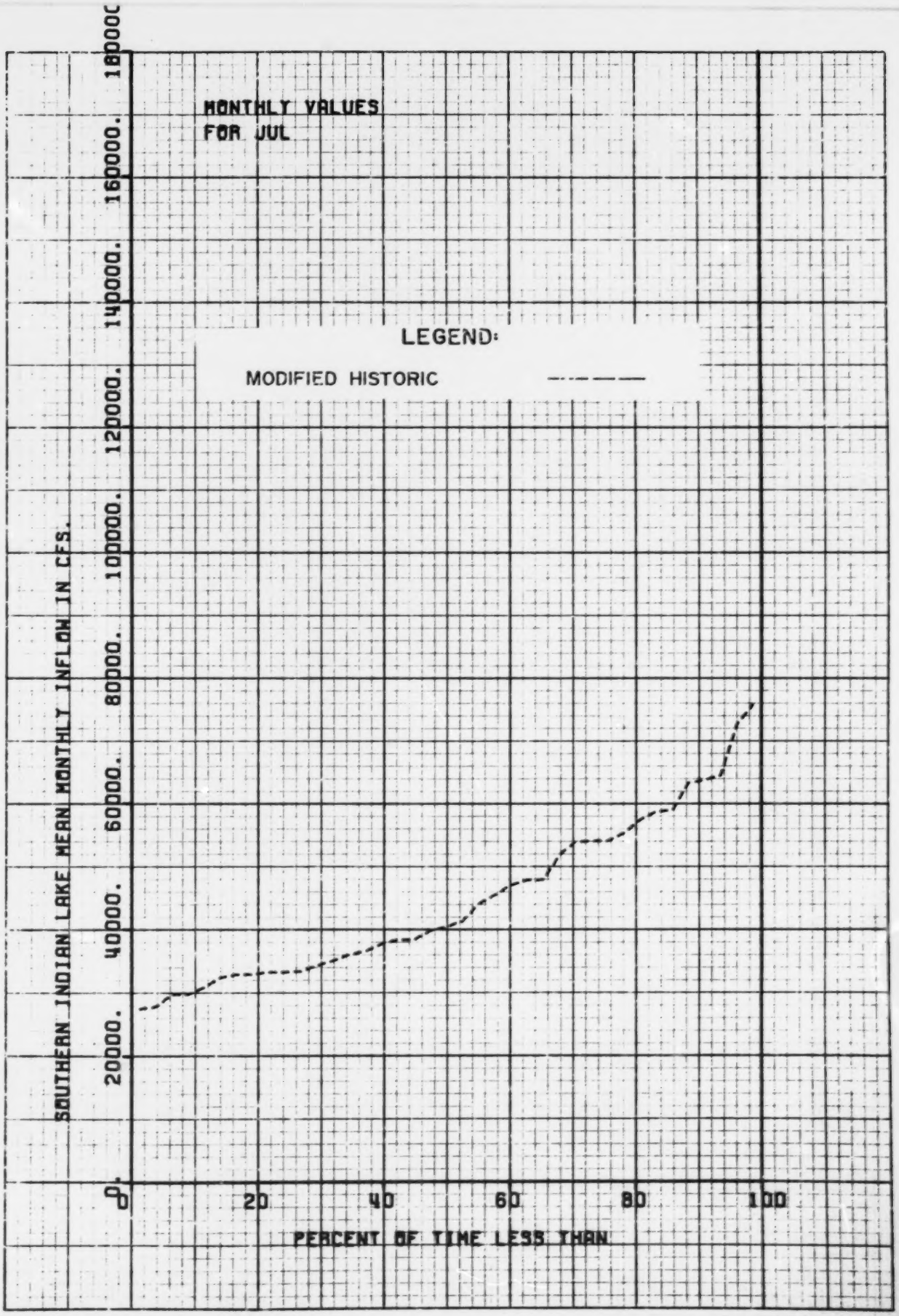
PERCENT OF TIME LESS THAN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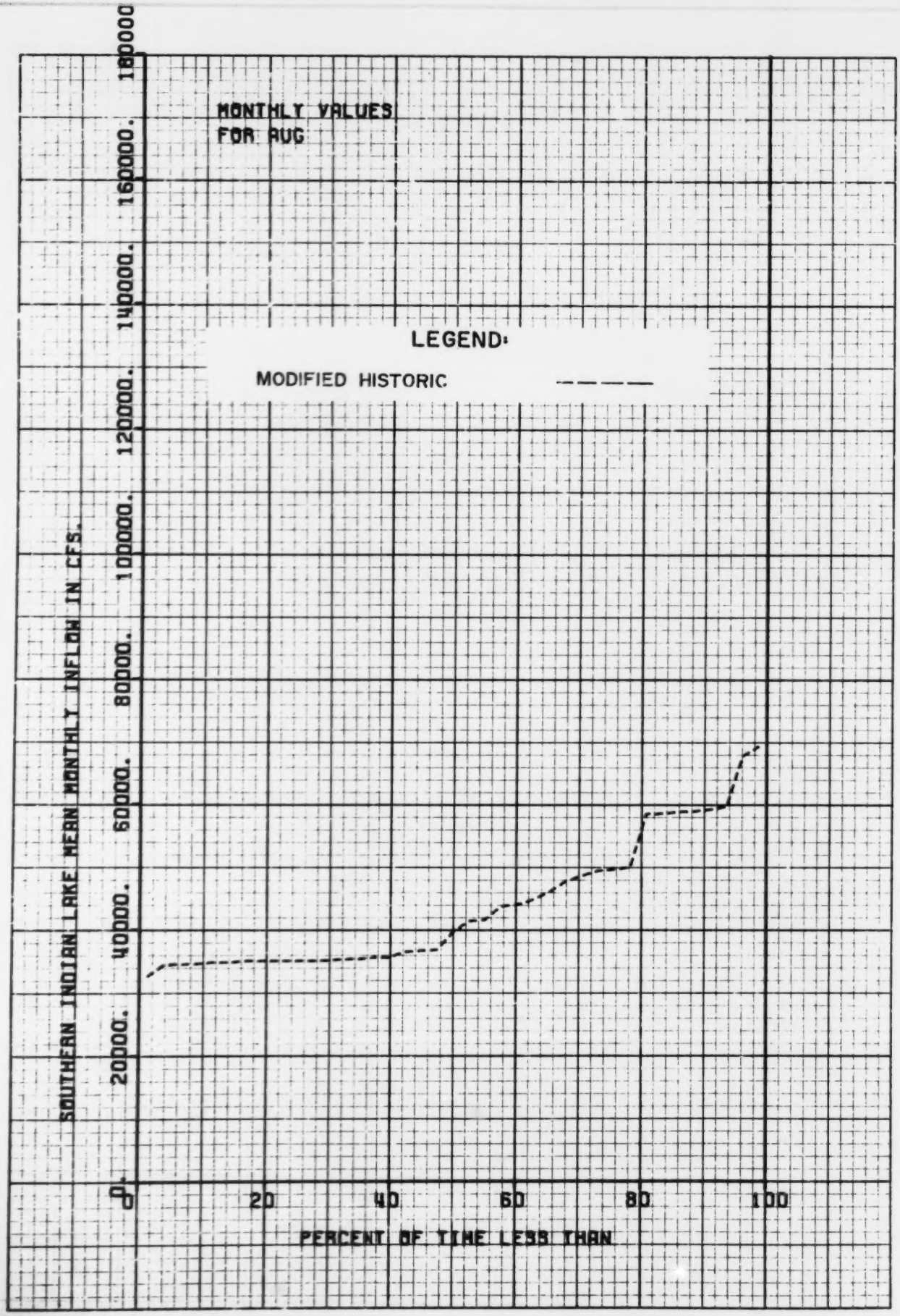
PERCENT OF TIME LESS THAN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LEGEND:
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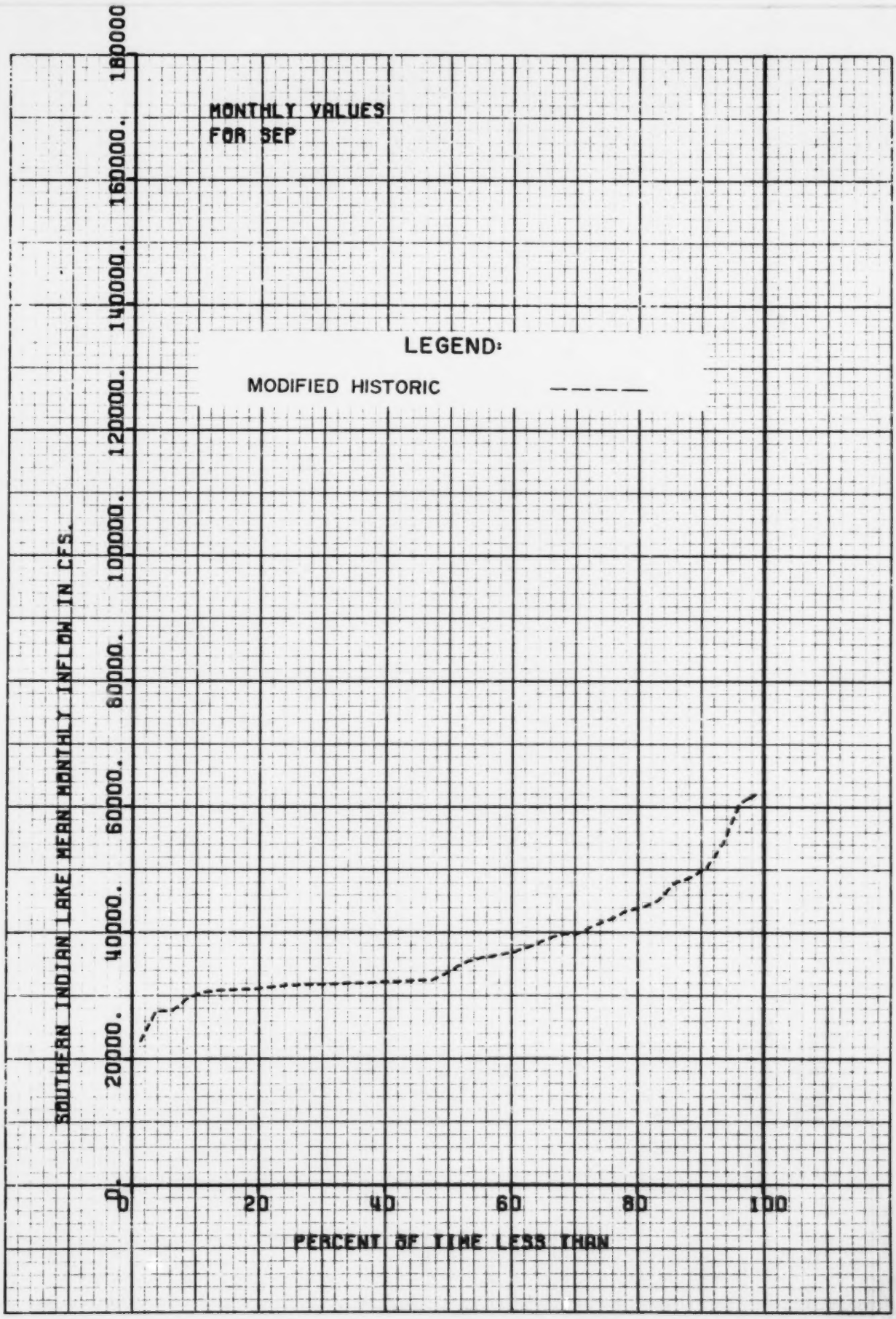
PERCENT OF TIME LESS THAN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LEGEND:
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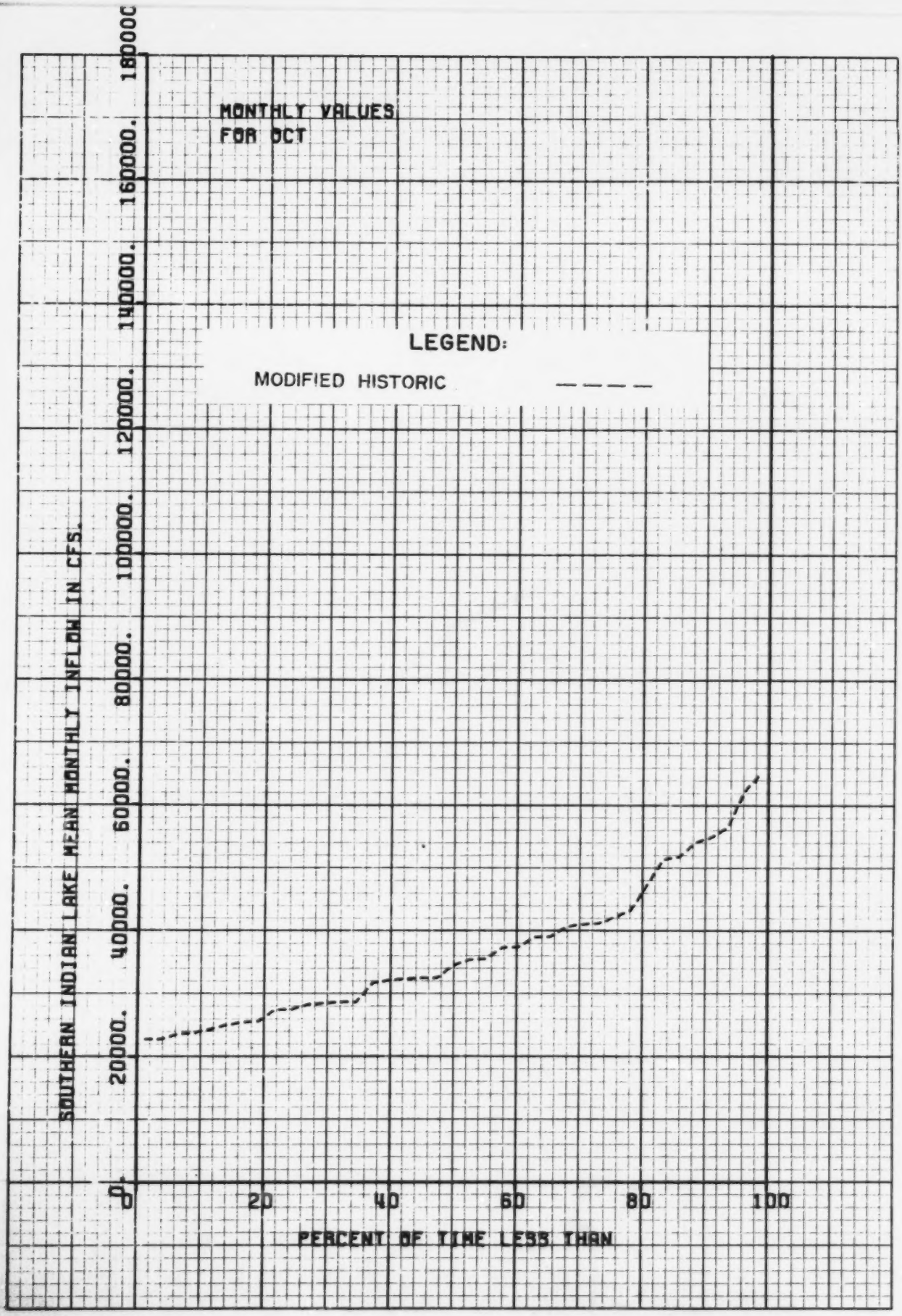
PERCENT OF TIME LESS THAN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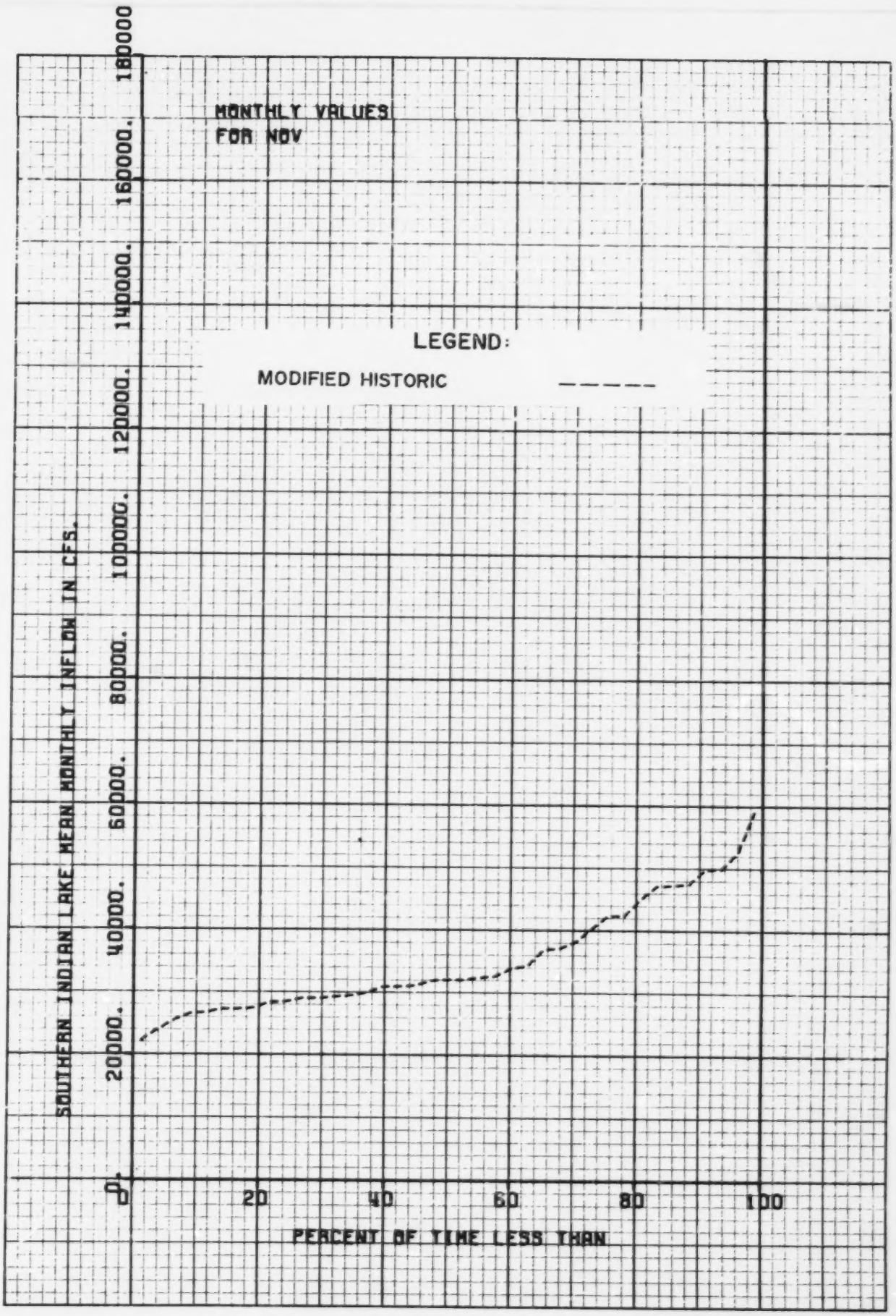
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
SOUTHERN INDIAN LAKE MEAN MONTHLY INFLOW IN CFS.
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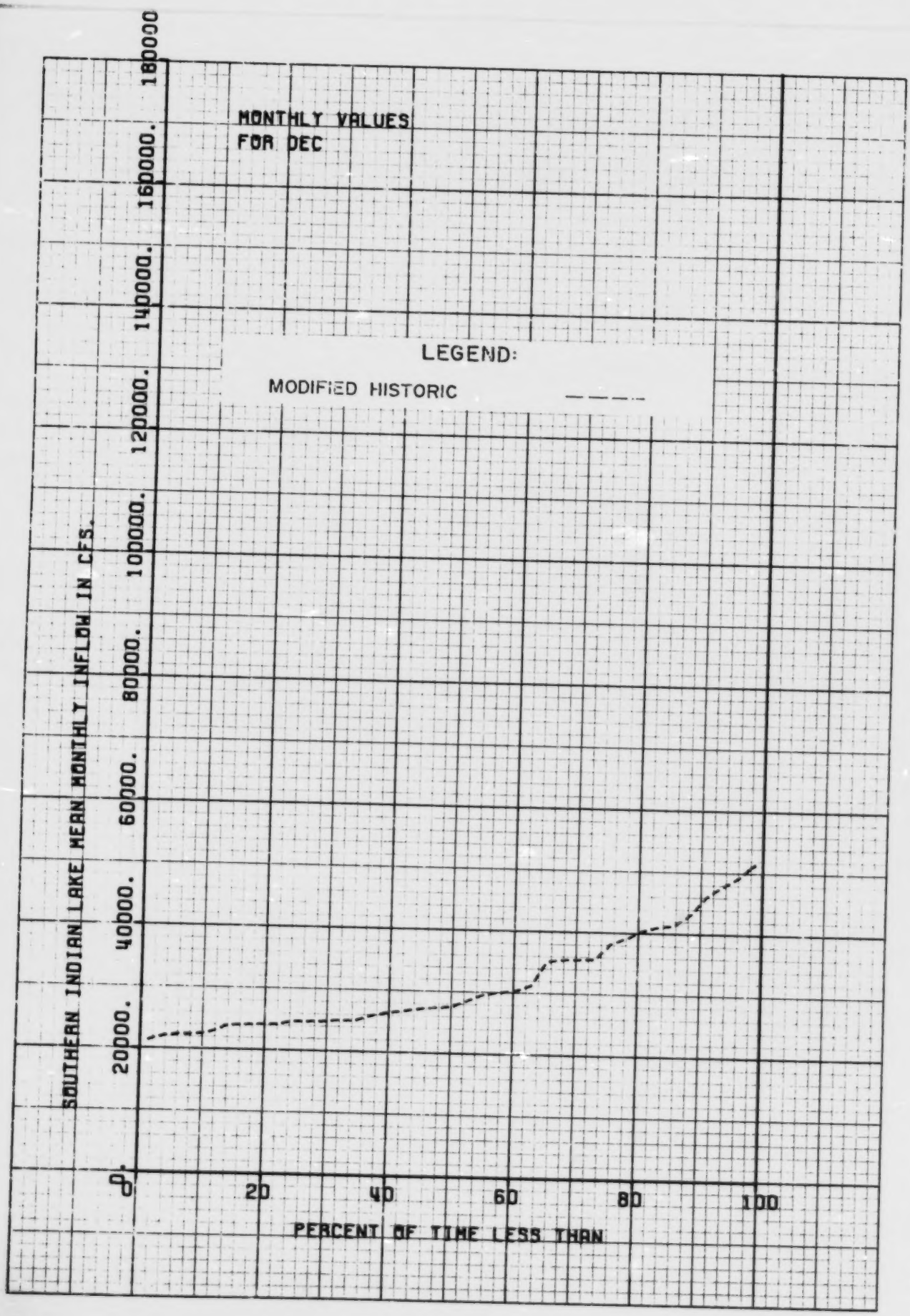
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
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PERCENT OF TIME LESS THAN

SECTION 5

LOWER CHURCHILL RIVER STUDY AREA

Partridge Breast Lake Levels

PARTRIDGE BREAST LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	8	79	0	89	18	74	42	58	58	16	47	0	61	0	71	18	37	45	5	68	8	82	5	89
1 - 2	0	13	0	11	0	8	0	0	24	0	21	0	29	0	8	3	3	13	5	19	5	5	0	5
2 - 4	0	0	0	0	0	0	0	0	3	0	29	0	11	0	0	0	0	3	0	3	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	801.06	800.70	800.74	800.50	800.44	801.28	801.89	802.39	802.49	801.74	801.38	801.09	800.44
AVERAGE	803.00	802.45	802.06	801.89	802.36	803.80	804.84	805.07	804.82	804.29	803.96	803.50	803.50
MAXIMUM	806.87	805.56	804.05	803.56	805.08	809.66	811.16	810.44	809.48	809.25	808.73	807.80	811.16

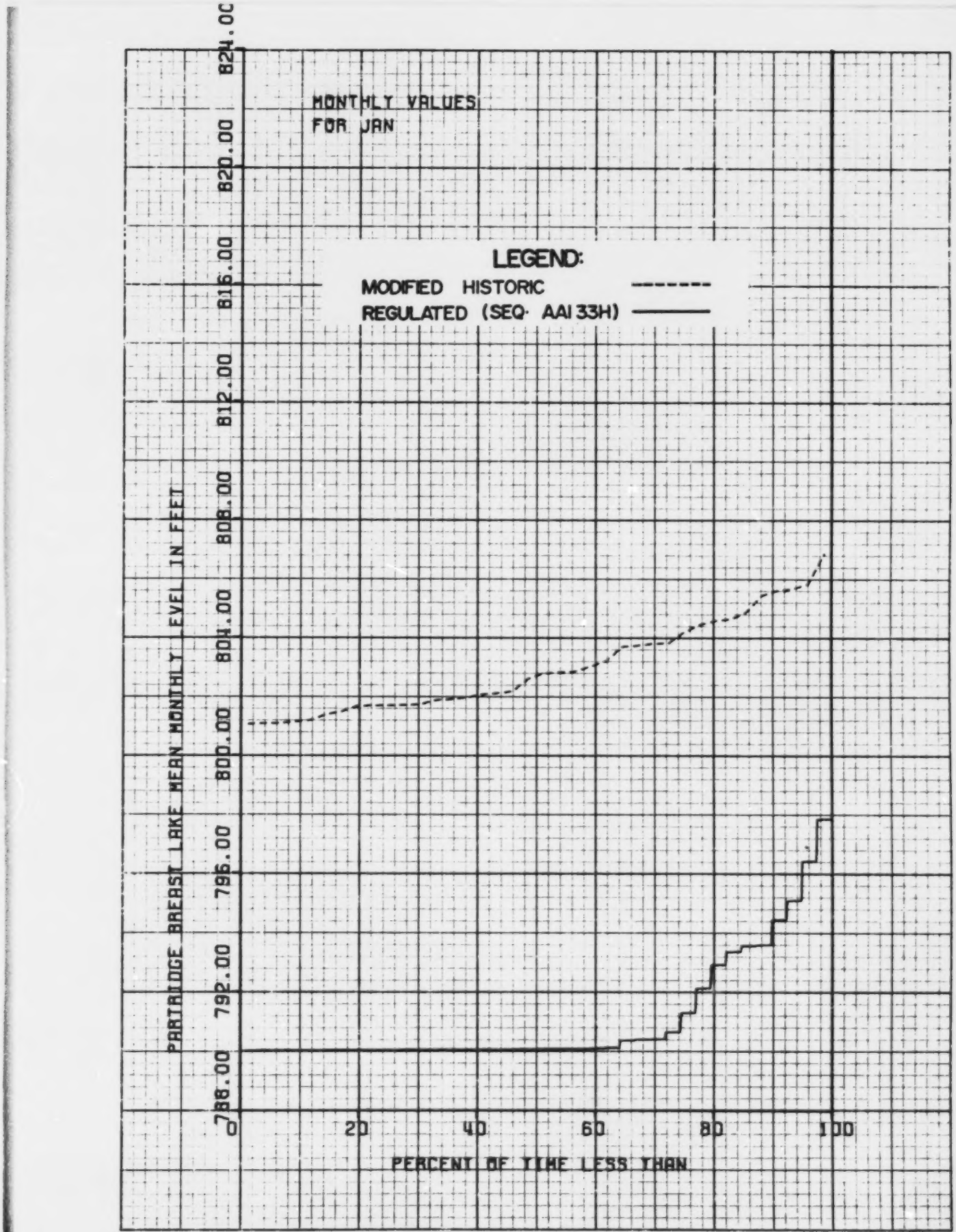
PARTRIDGE BREAST LAKE - REGULATED CONDITIONS

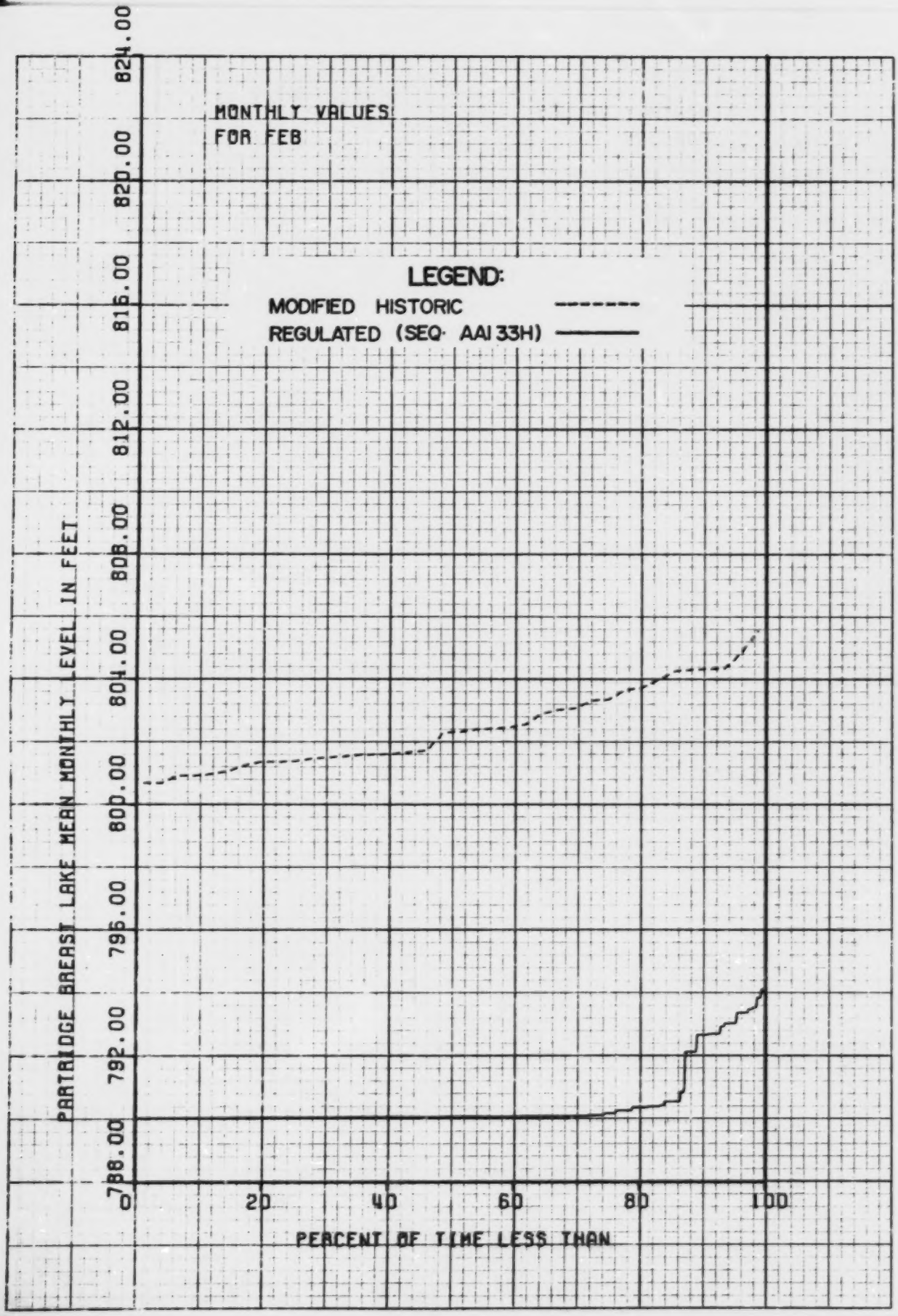
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

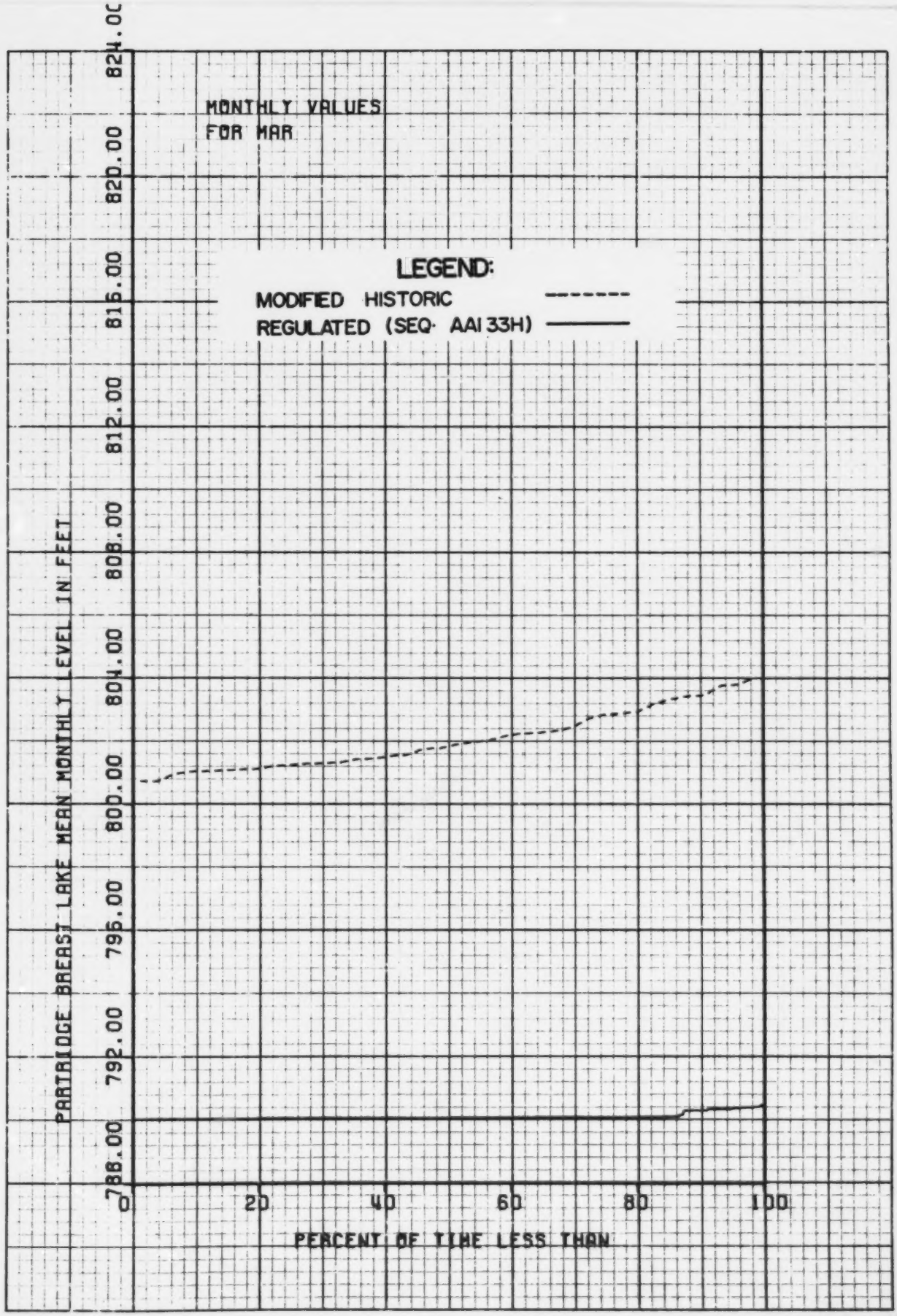
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	20	44	14	65	46	41	50	41	7	0	1	12	16	11	9	21	1	0	8	26	7	22	37	24
1 - 2	0	0	0	8	0	2	2	0	2	48	4	0	2	12	9	28	0	11	8	9	32	10	0	21
2 - 4	0	28	0	8	0	11	1	0	0	0	11	0	3	34	8	16	5	52	8	37	2	19	2	13
4 - 6	0	8	0	5	0	0	3	0	7	0	25	0	7	12	1	5	0	26	3	0	0	2	0	3
6 - 8	0	0	0	0	0	0	1	0	13	0	22	0	2	0	0	2	0	2	0	0	0	1	0	0
8 -	0	0	0	0	0	0	0	0	22	0	25	0	0	0	0	0	0	2	3	0	0	4	0	0

MEAN MONTHLY LEVELS IN FEET

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	790.02	790.02	790.00	790.00	788.58	788.36	788.40	788.51	788.62	788.39	789.79	790.03	788.36
AVERAGE	791.12	790.45	790.07	790.38	793.48	799.44	798.33	797.29	794.00	794.05	793.07	792.31	793.66
MAXIMUM	797.84	794.09	790.45	797.01	806.52	810.58	806.64	804.66	802.86	809.21	802.23	800.12	810.58


MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
788.00
792.00
796.00
800.00
804.00
808.00
812.00
816.00
820.00
824.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
824.00
820.00
816.00
812.00
808.00
804.00
800.00
796.00
792.00
788.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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LEGEND:
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PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
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800.00
804.00
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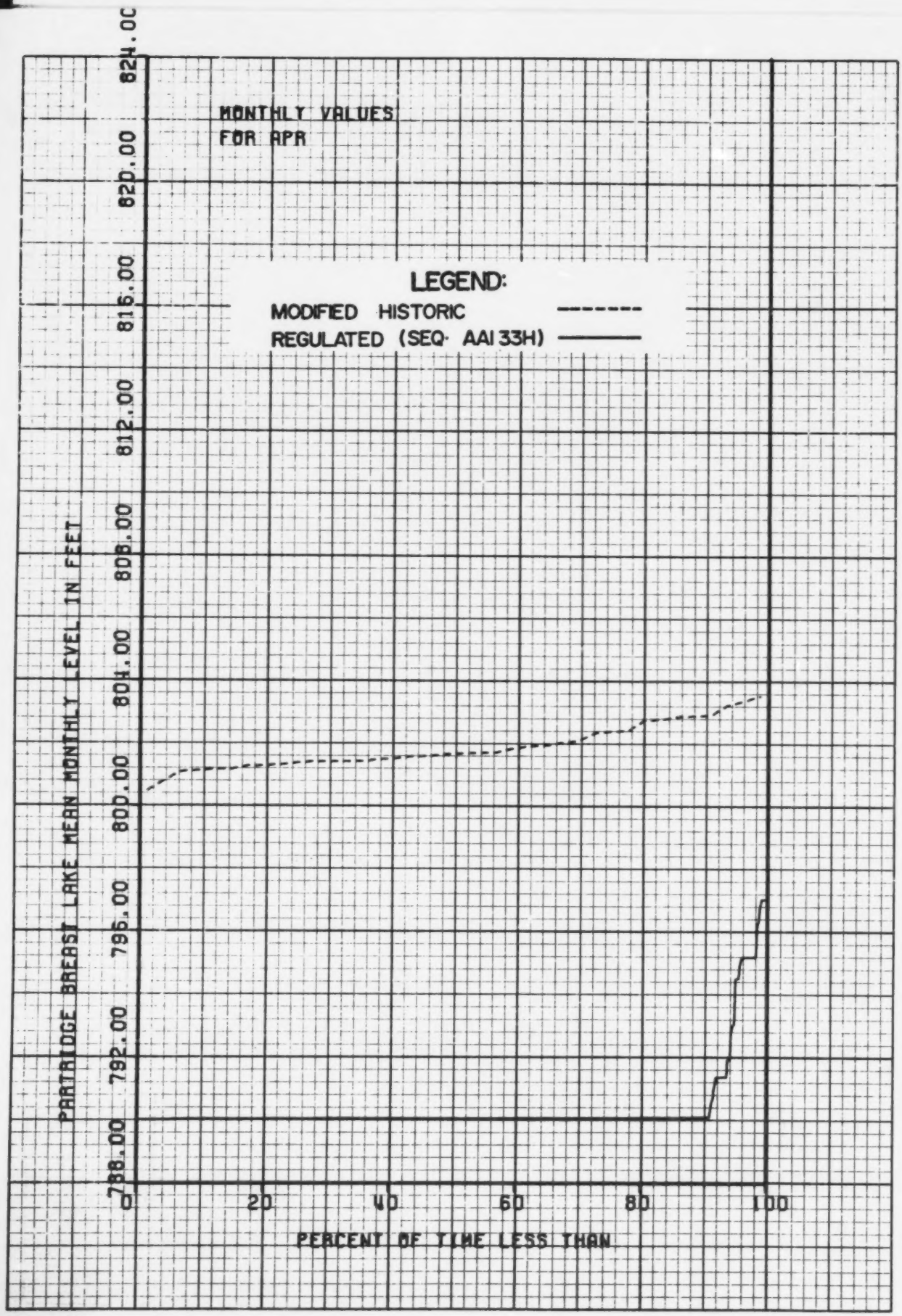
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
824.00
820.00
816.00
812.00
808.00
804.00
800.00
796.00
792.00
788.00
0
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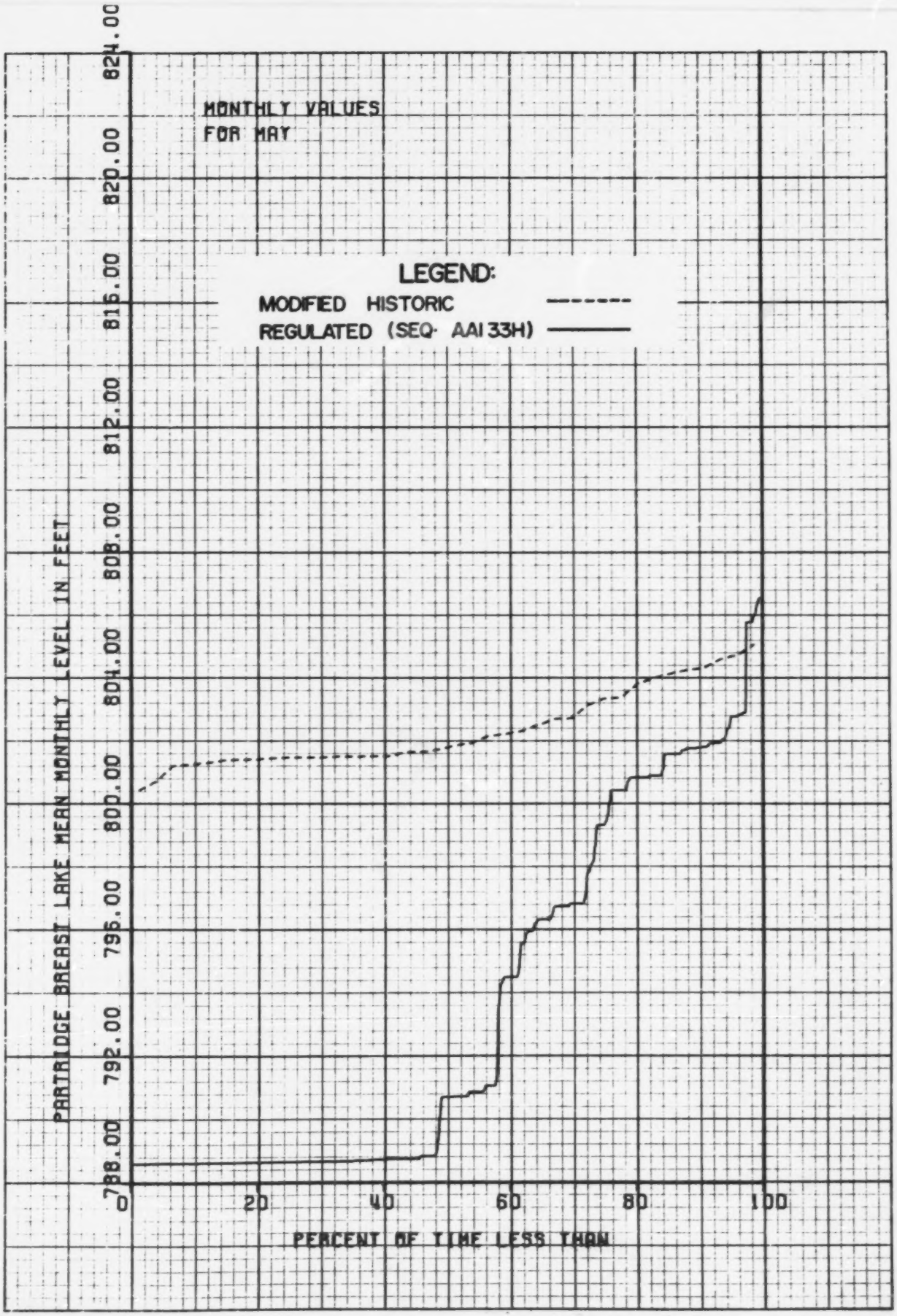
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
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792.00
796.00
800.00
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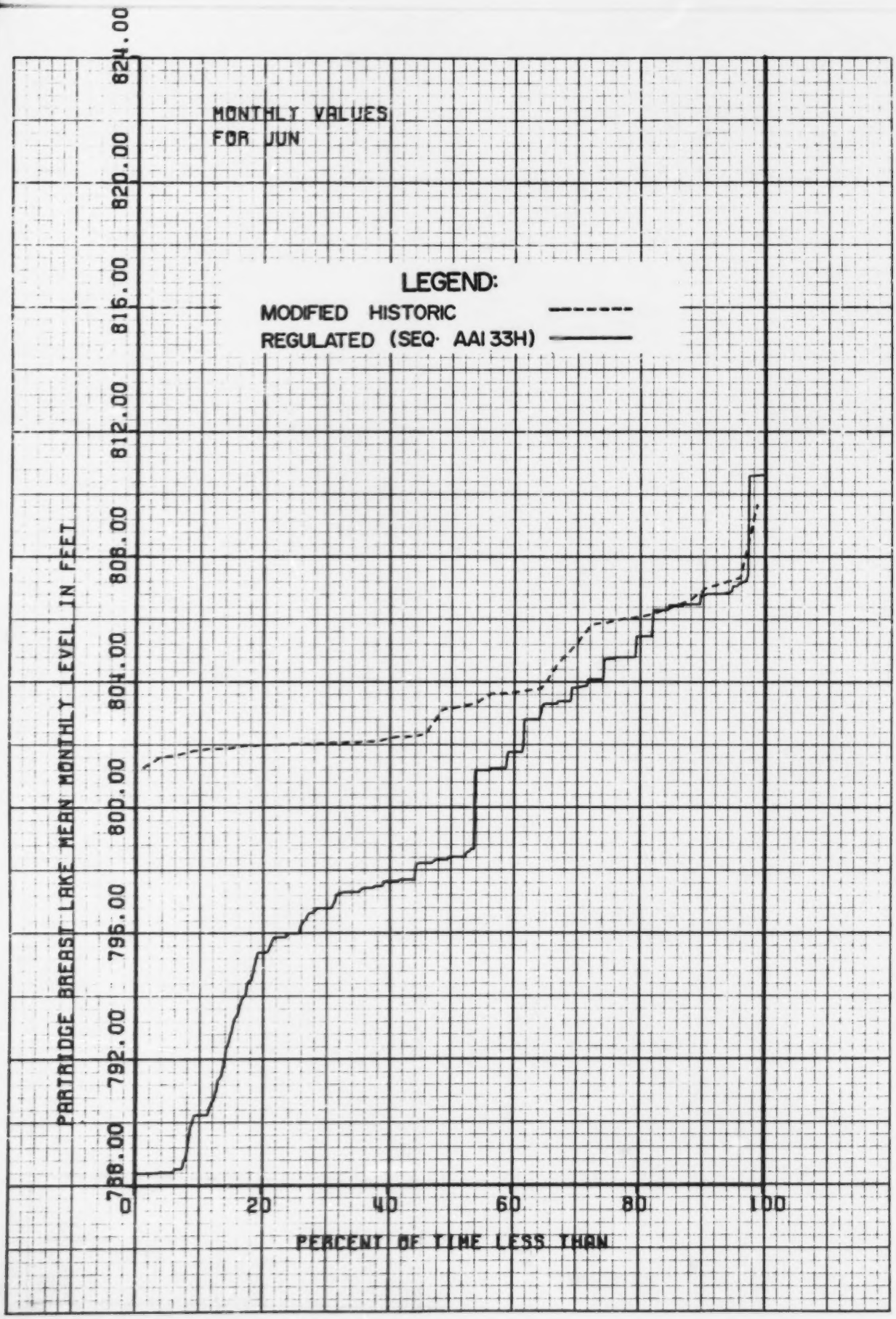
PERCENT OF TIME LESS THAN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FOR JUN
LEGEND:
MODIFIED HISTORIC
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PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
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820.00
816.00
812.00
808.00
804.00
800.00
796.00
792.00
788.00
0
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40
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80
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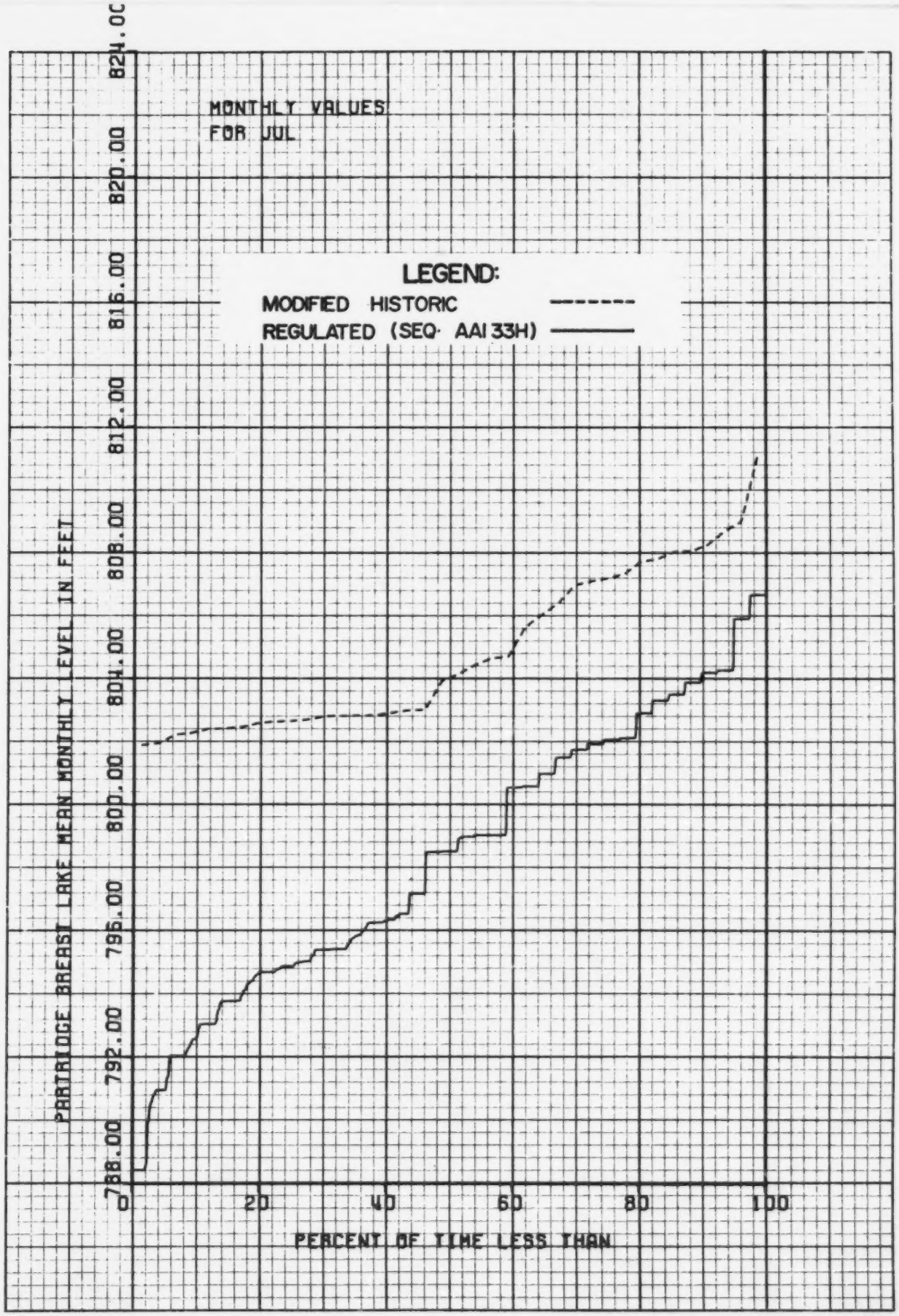
PERCENT OF TIME LESS THAN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FOR JUL
LEGEND:
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792.00
796.00
800.00
804.00
808.00
812.00
816.00
820.00
824.00
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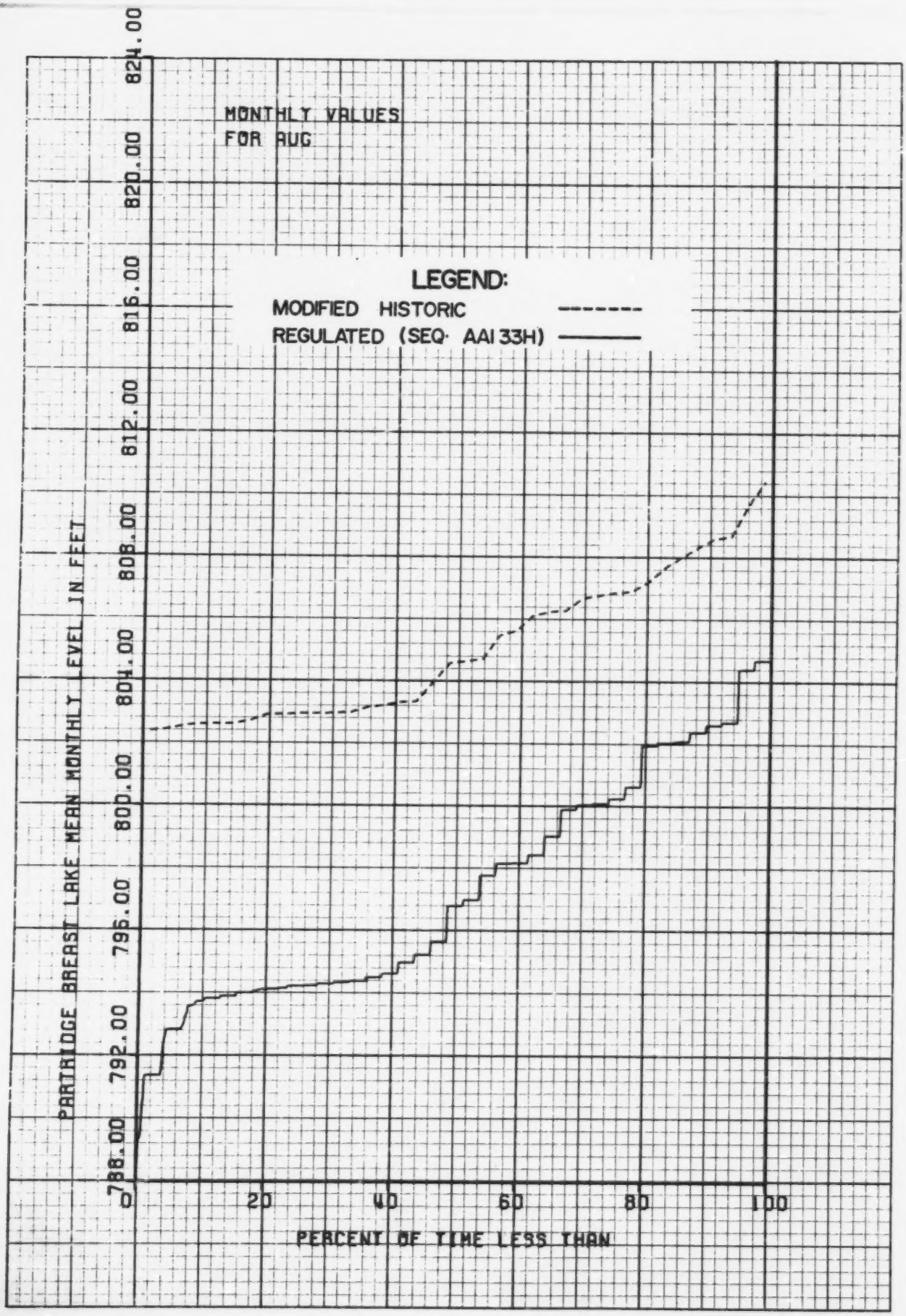
PERCENT OF TIME LESS THAN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FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
788.00
792.00
796.00
800.00
804.00
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820.00
824.00
0
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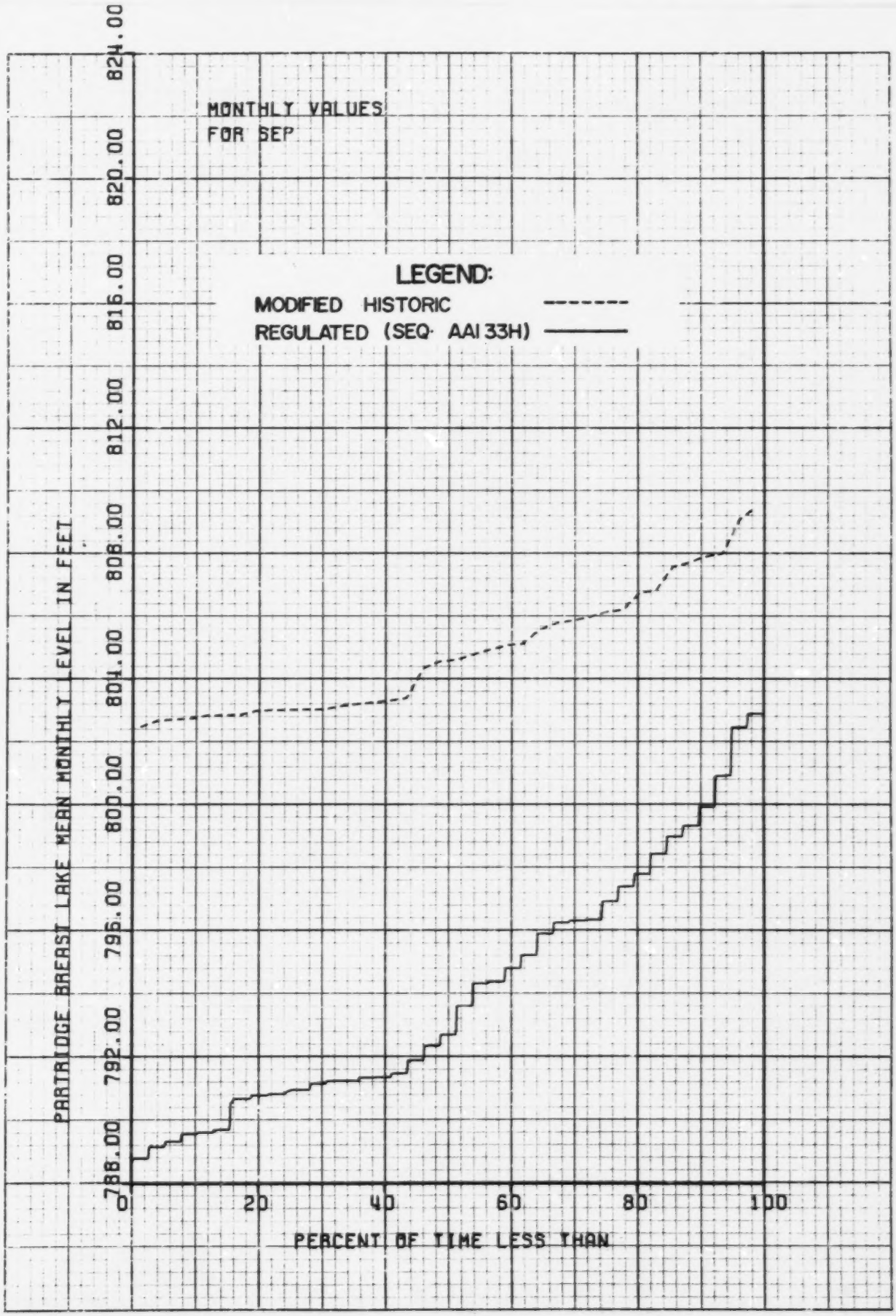
PERCENT OF TIME LESS THAN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LEGEND:
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REGULATED (SEQ. AAI33H)
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788.00
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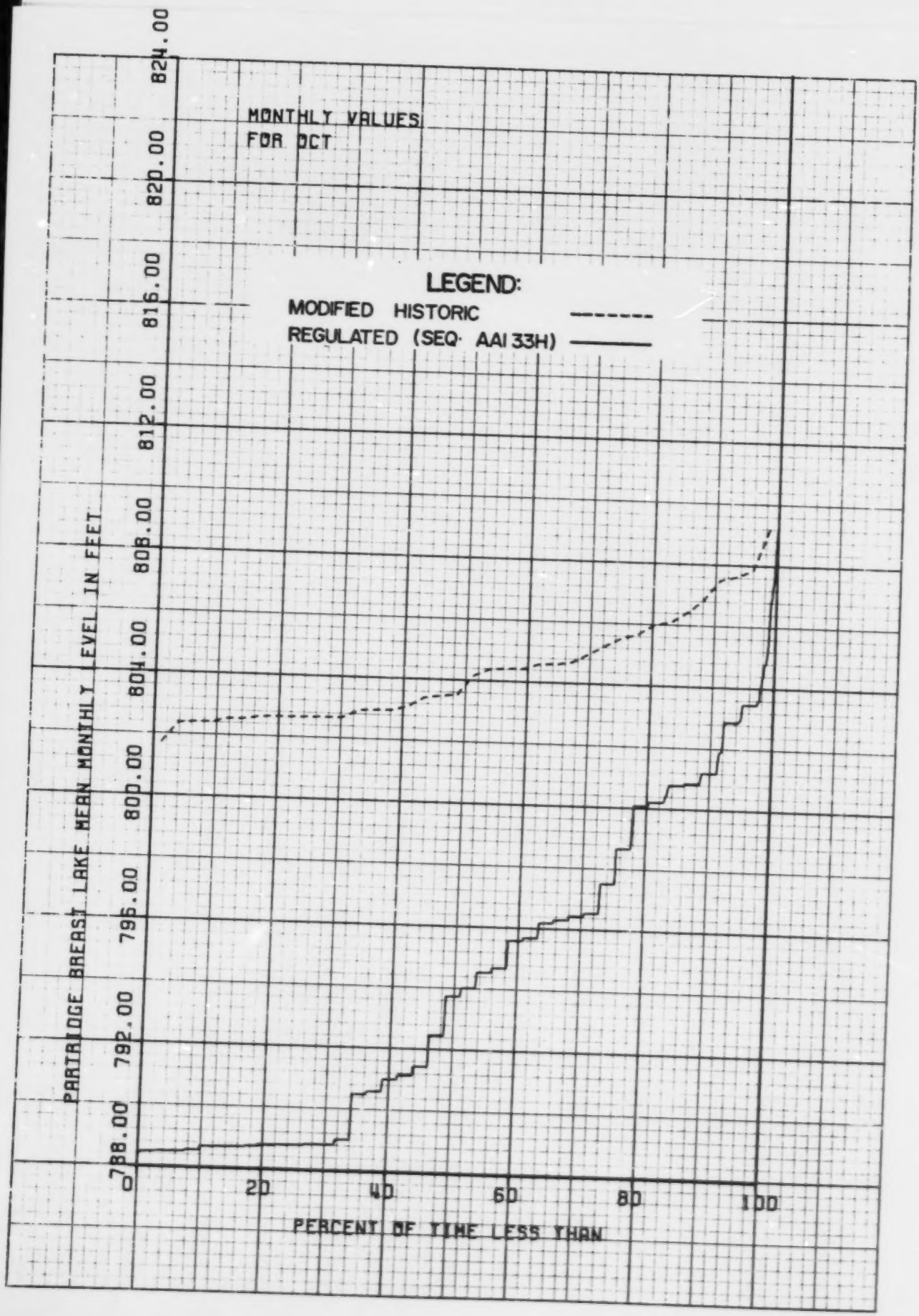
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
788.00
792.00
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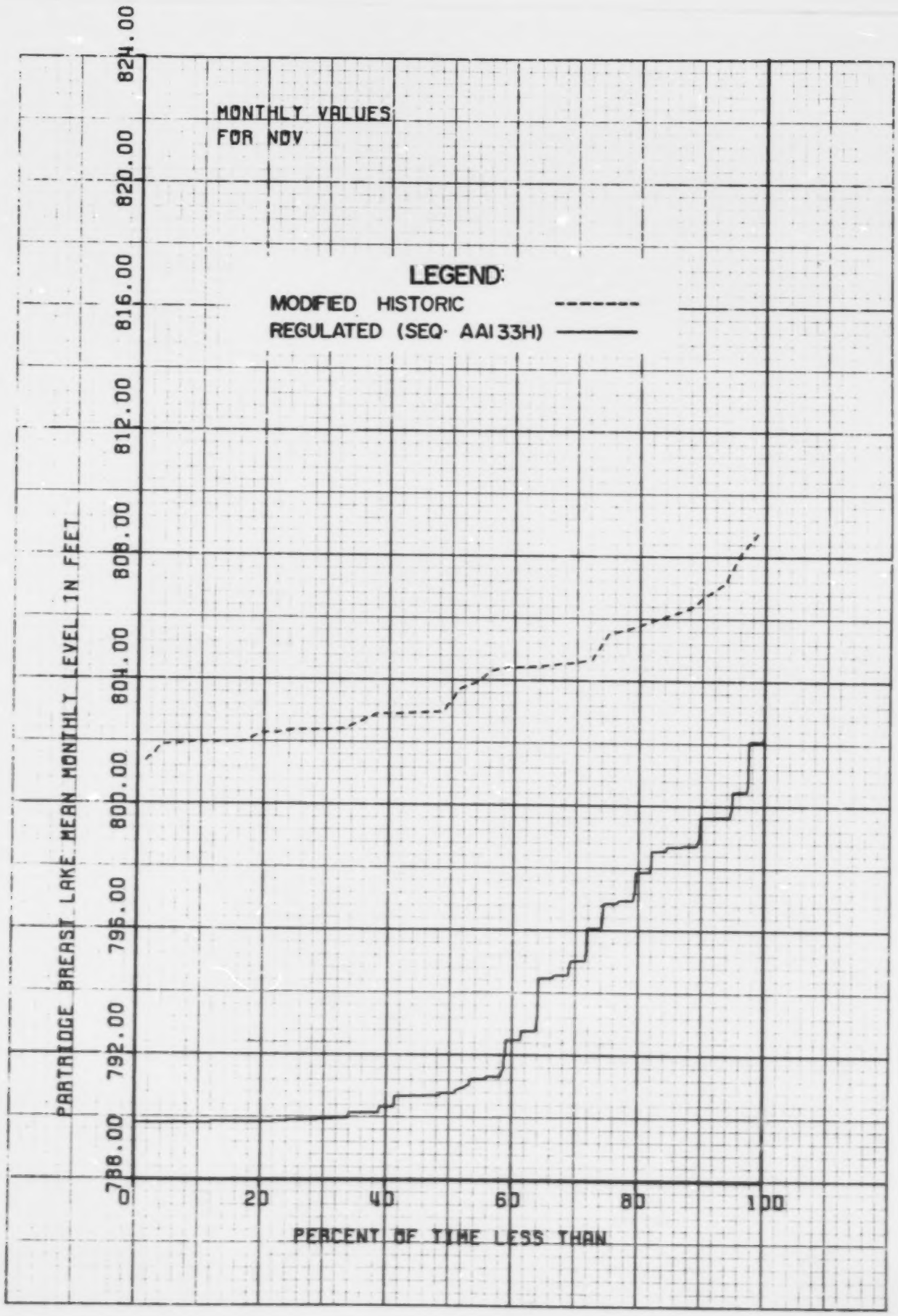
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODFIED HISTORIC
REGULATED (SEQ· AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
824.00
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804.00
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796.00
792.00
788.00
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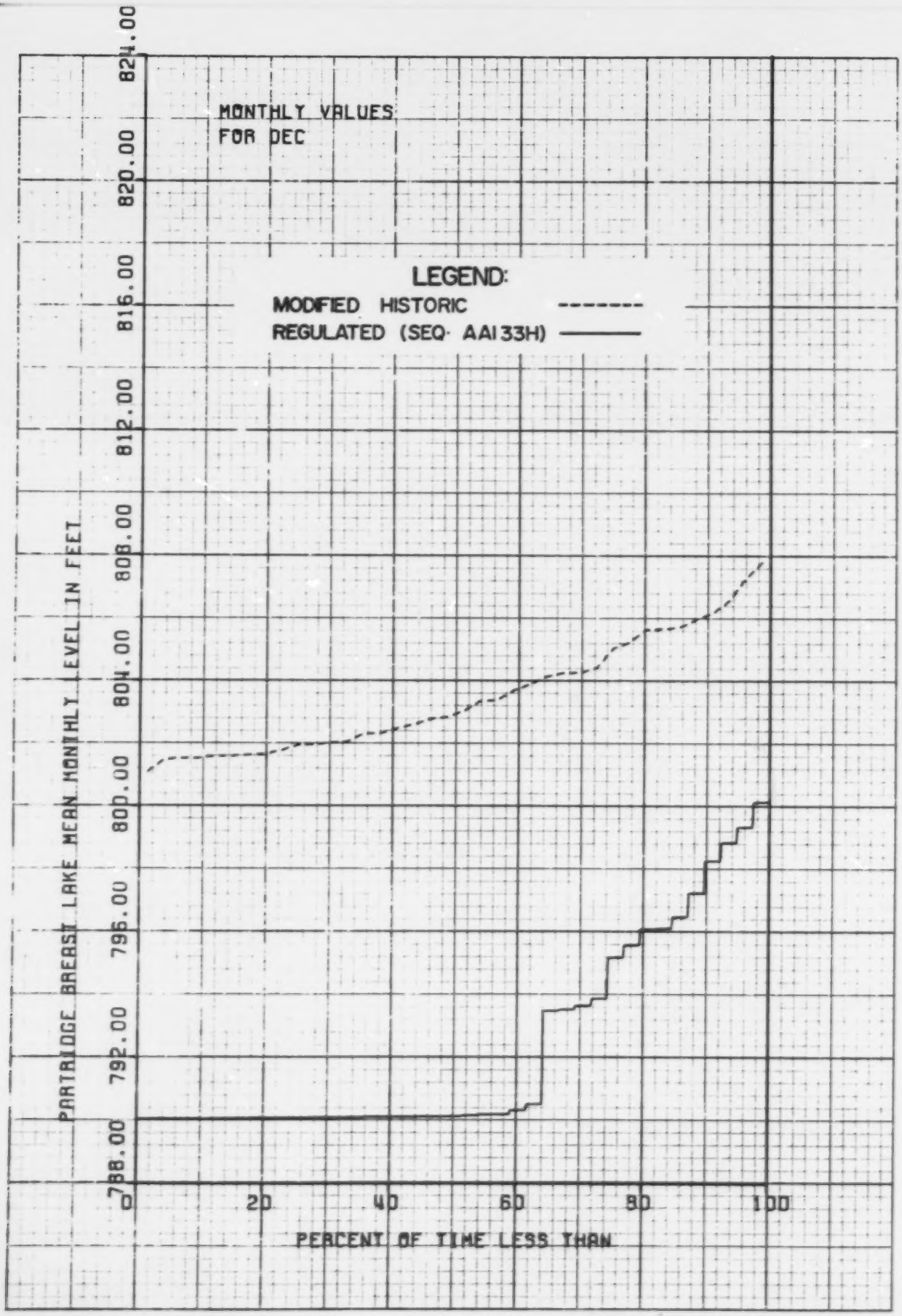
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY LEVEL IN FEET
824.00
820.00
816.00
812.00
808.00
804.00
800.00
796.00
792.00
788.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

PARTRIDGE BREAST LAKE
OUTFLOWS

PARTRIDGE BREAST LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	8	82	0	92	18	74	42	58	61	16	53	0	68	0	68	21	37	42	5	68	5	84	5	89
5 - 10	0	11	0	8	0	8	0	0	21	0	21	0	18	0	8	3	3	16	5	19	5	5	0	5
10 - 20	0	0	0	0	0	0	0	0	3	0	24	0	13	0	0	0	0	3	0	3	0	0	0	0
20 - 30	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

MINIMUM	25,380	23,960	24,150	23,210	23,000	26,180	28,530	30,480	30,860	27,980	26,580	25,460	ANNUAL 23,000
AVERAGE	33,458	31,057	29,339	28,611	30,672	37,257	42,301	43,270	41,872	39,304	37,824	35,762	35,894
MAXIMUM	51,880	44,850	37,850	35,550	42,630	67,880	77,050	72,580	66,740	65,300	62,070	56,850	77,050

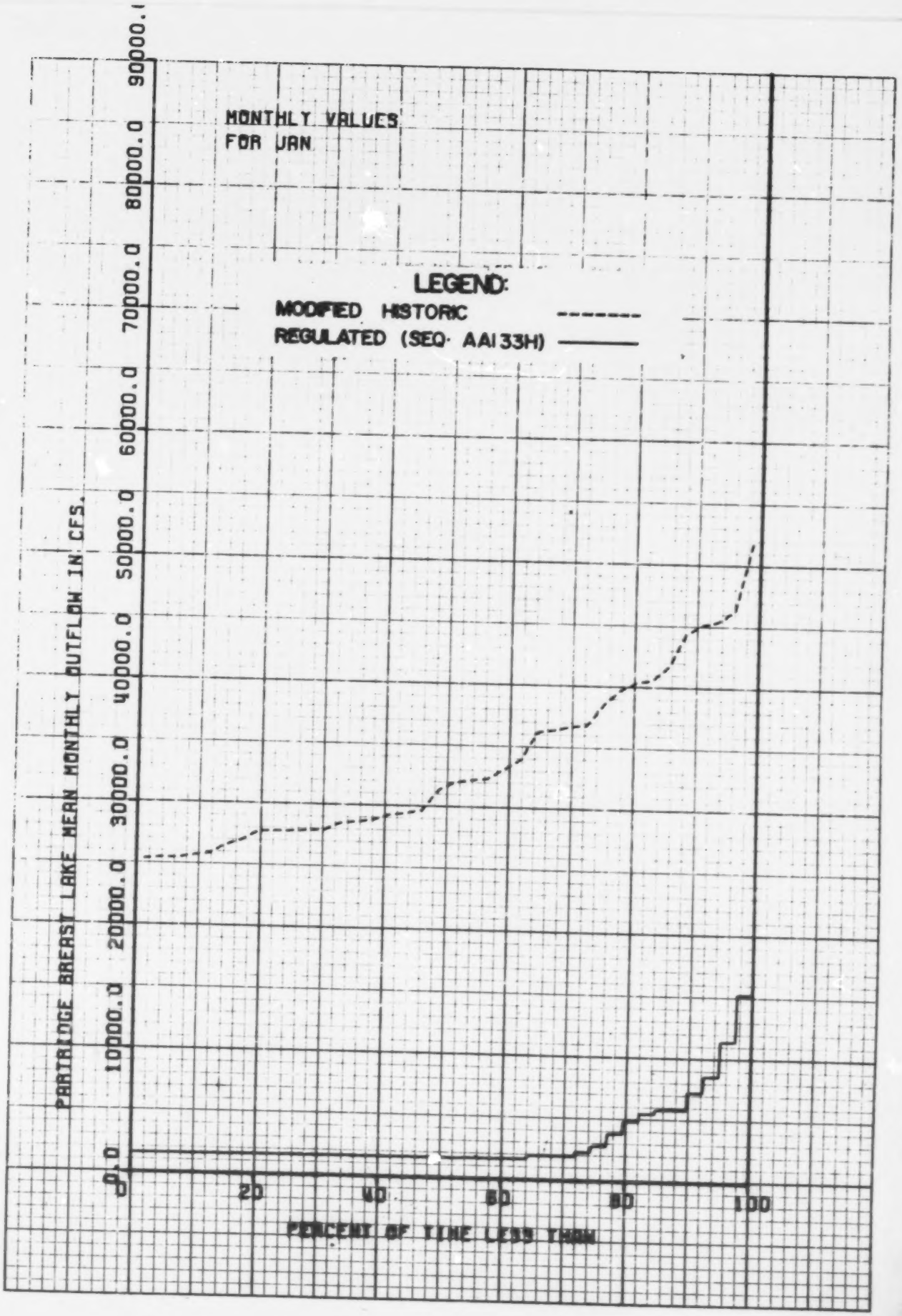
PARTRIDGE BREAST LAKE - REGULATED CONDITIONS

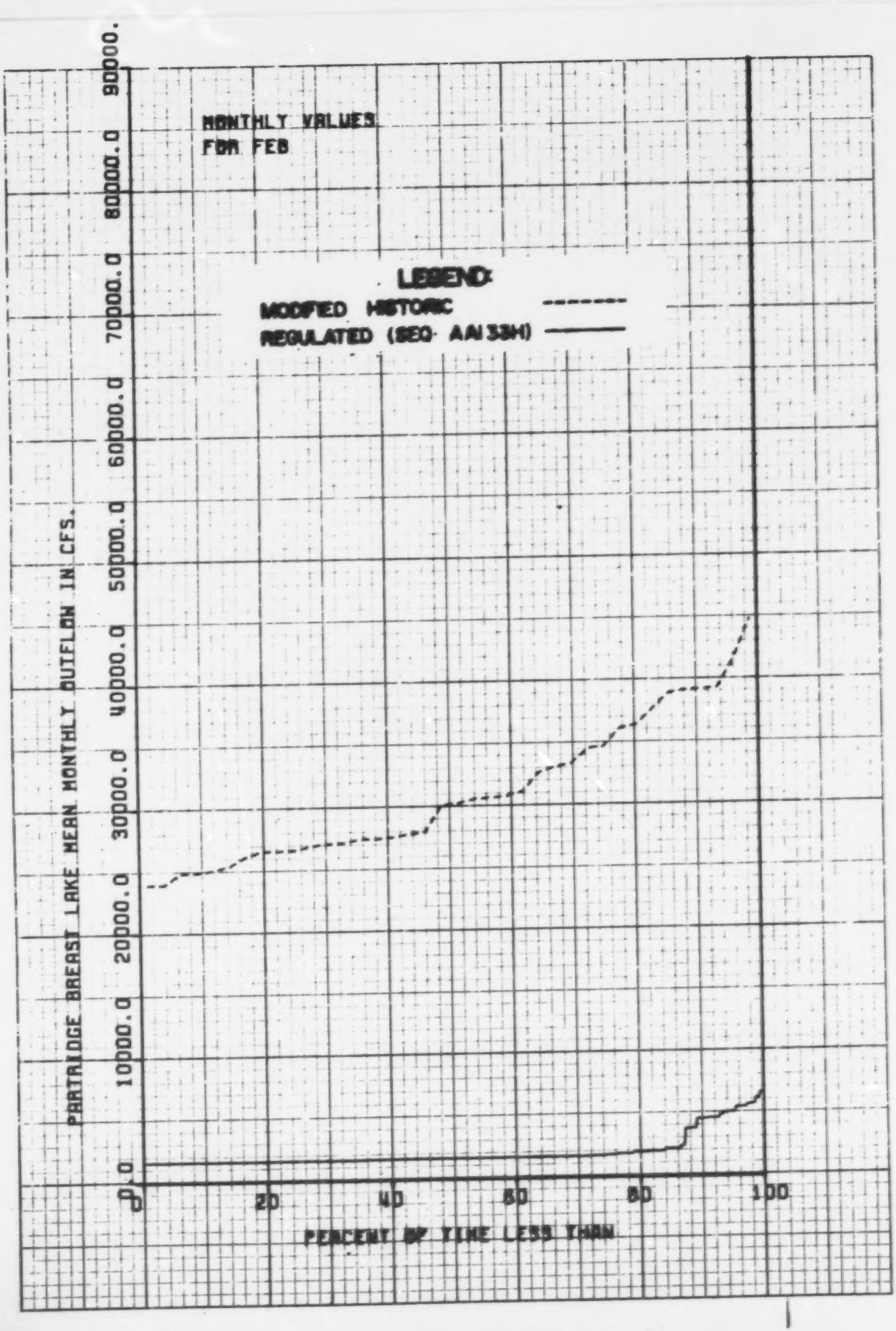
AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	20	61	14	79	54	46	55	40	10	49	9	13	21	18	21	44	3	37	18	64	39	41	37	48
5 - 10	0	13	0	6	0	0	4	0	8	0	13	0	10	20	3	12	2	28	5	8	2	7	2	10
10 - 20	0	5	0	2	0	0	1	0	14	0	39	0	0	26	2	18	0	26	3	0	0	5	0	3
20 - 30	0	0	0	0	0	0	0	0	16	0	17	0	0	5	0	0	0	0	3	0	0	3	0	0
30 - 40	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	2	0	0	0	2	0	0
40 -	0	0	0	0	0	0	0	0	2	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN C.F.S.

MINIMUM	1,520	1,520	1,510	1,500	660	540	560	620	690	560	1,380	1,530	ANNUAL 540
AVERAGE	3,012	2,012	1,572	2,016	9,847	24,795	19,199	15,423	8,505	10,047	6,888	5,195	9,043
MAXIMUM	15,220	6,560	1,960	13,200	50,530	73,410	50,570	40,660	32,290	65,030	29,940	21,720	73,410


MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
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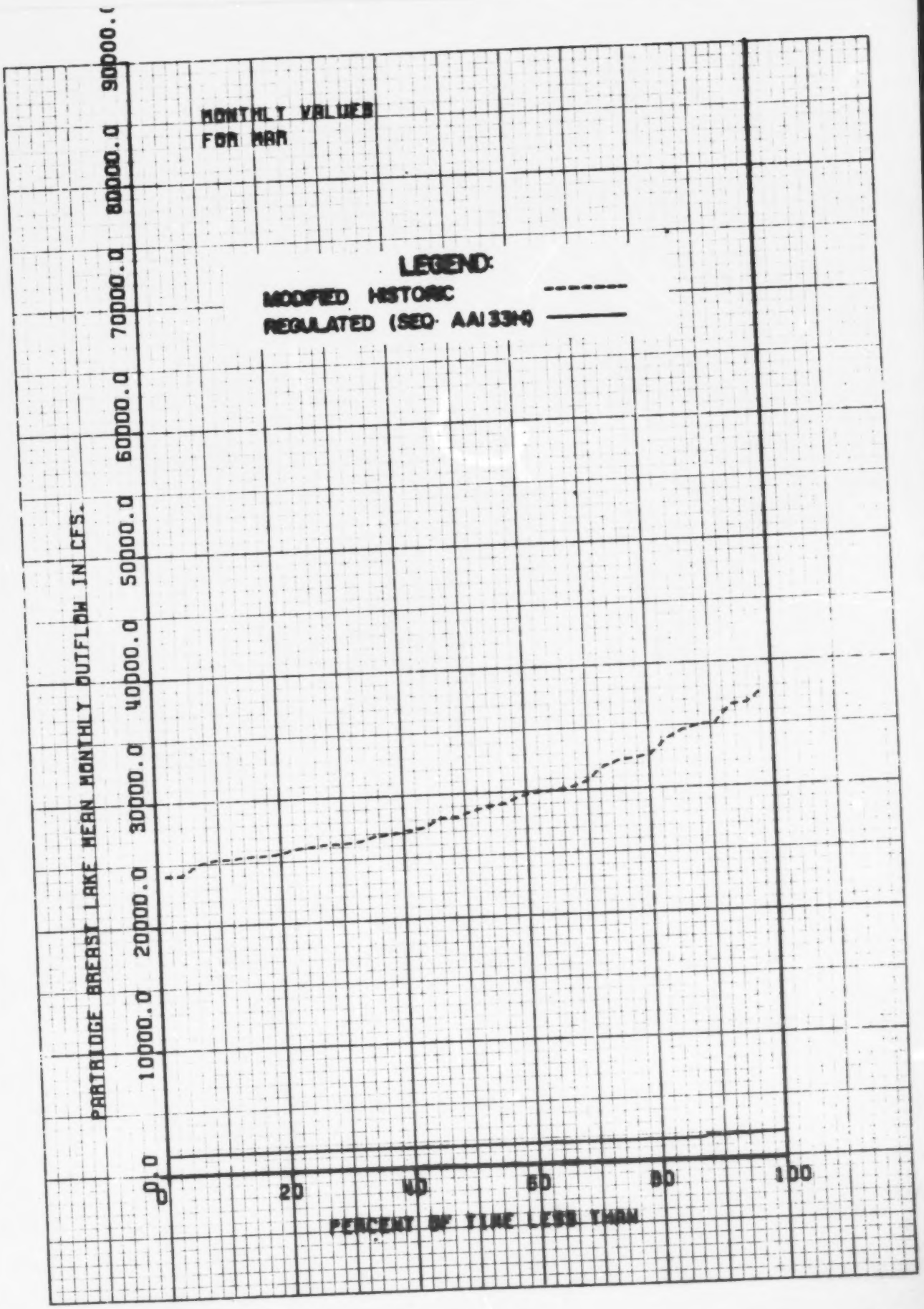
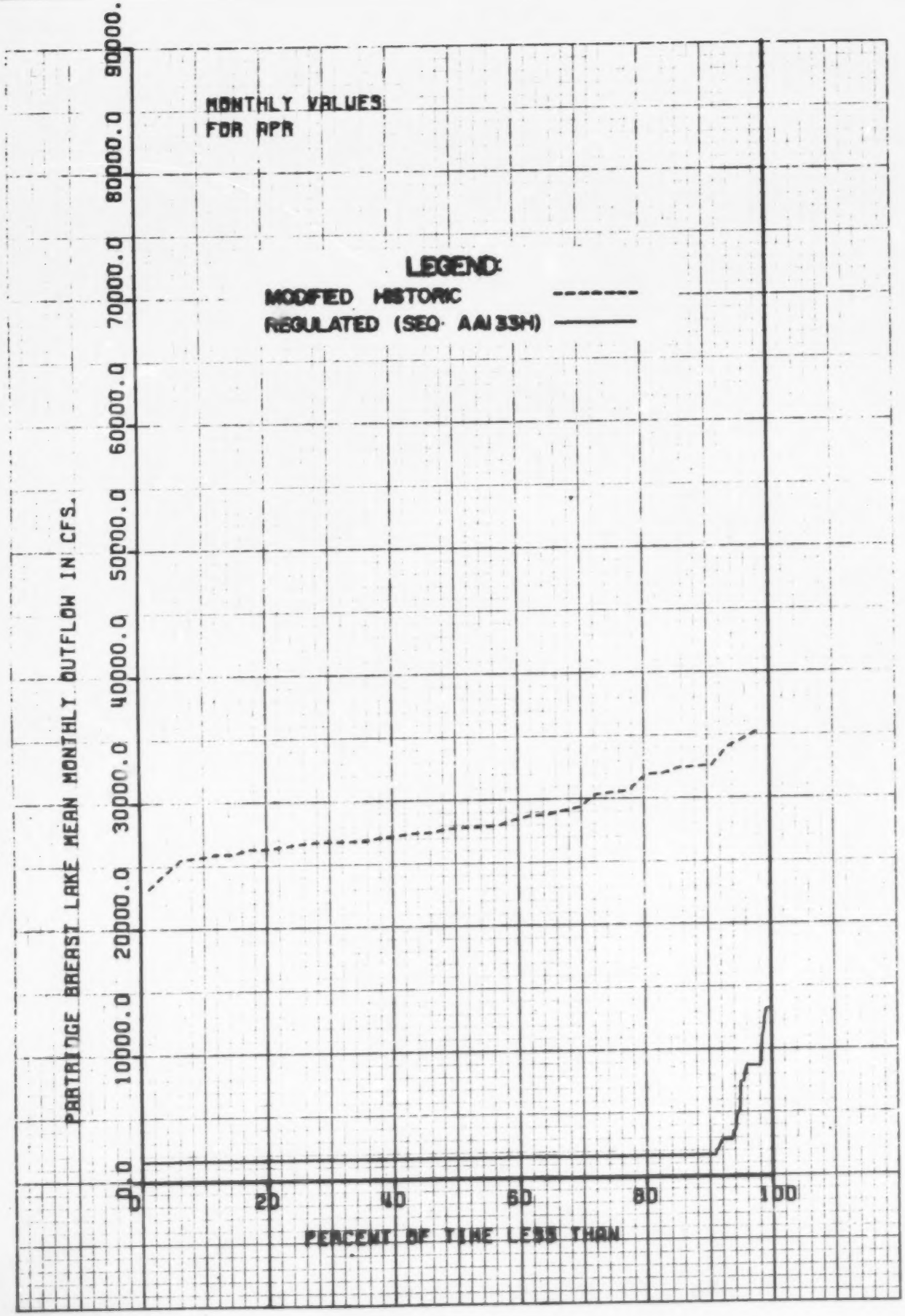
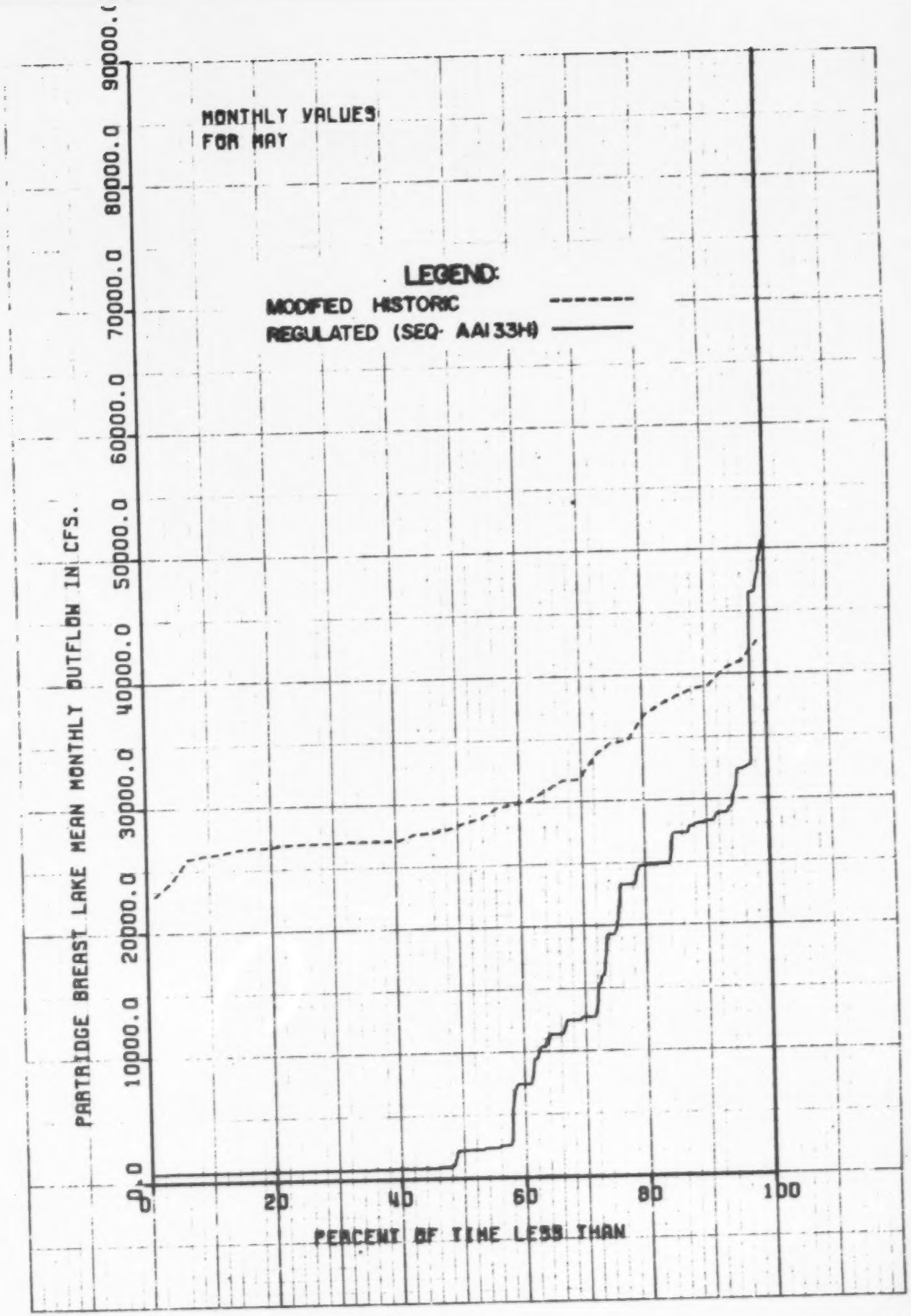
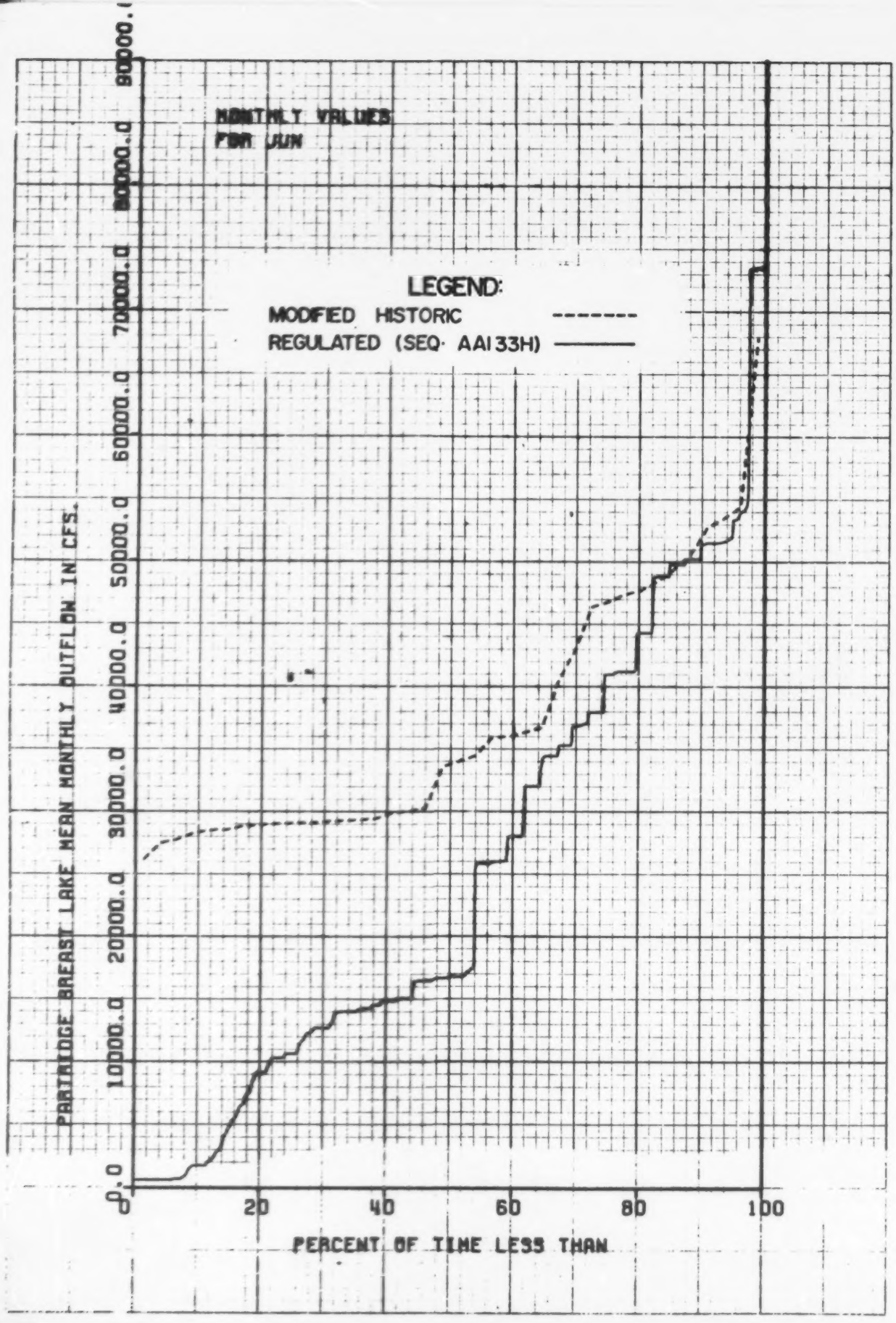
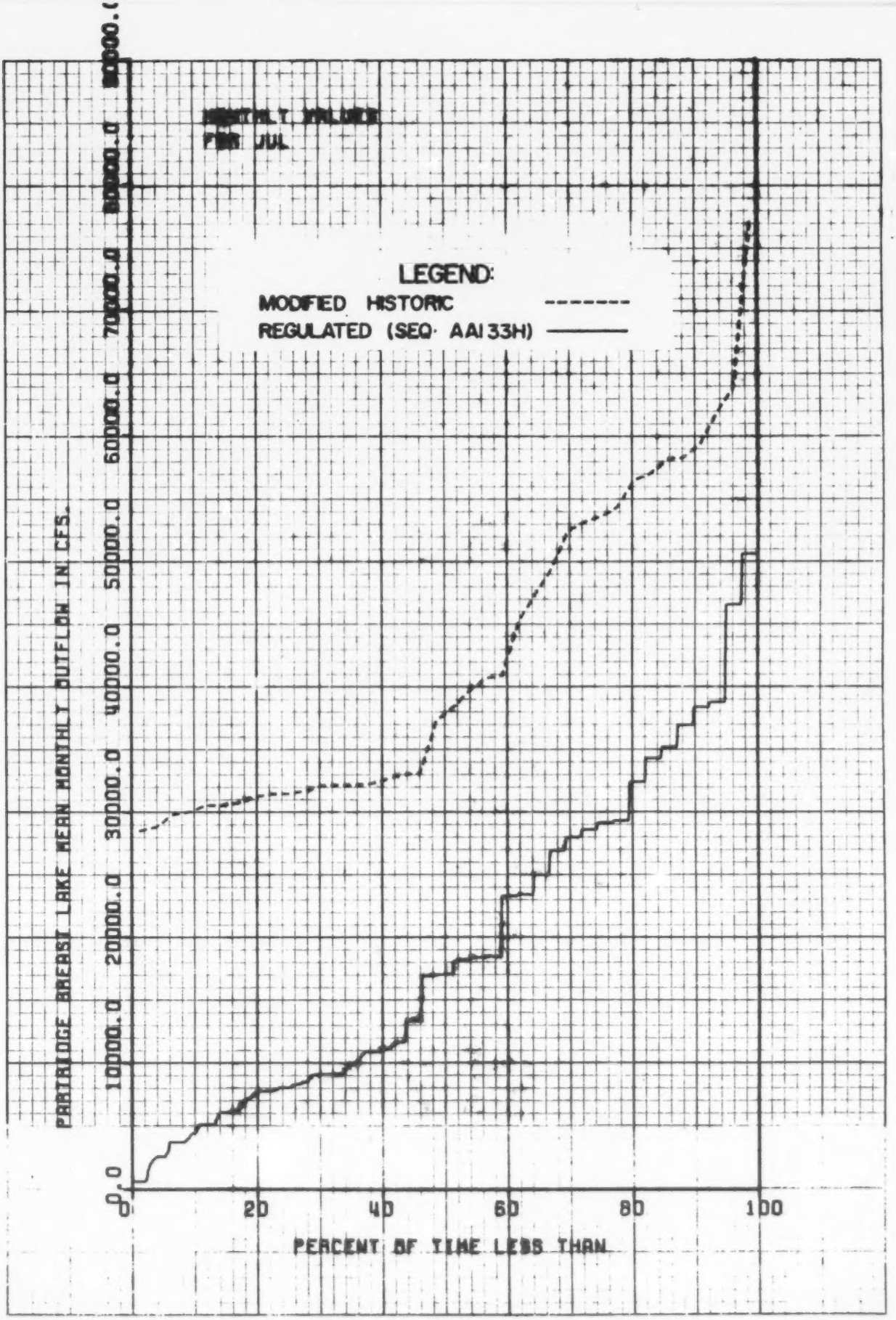
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

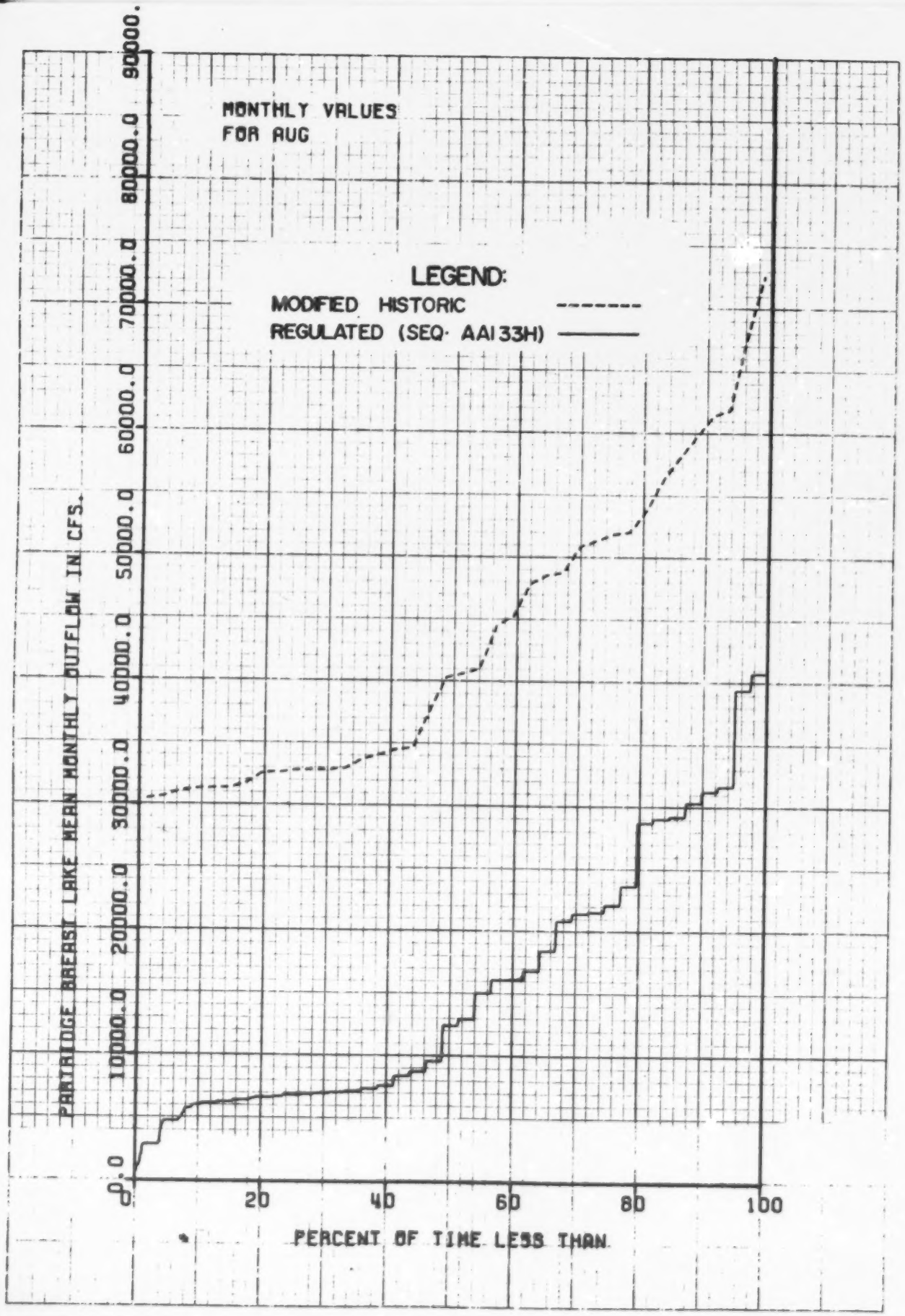

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SED. AAI33M)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN

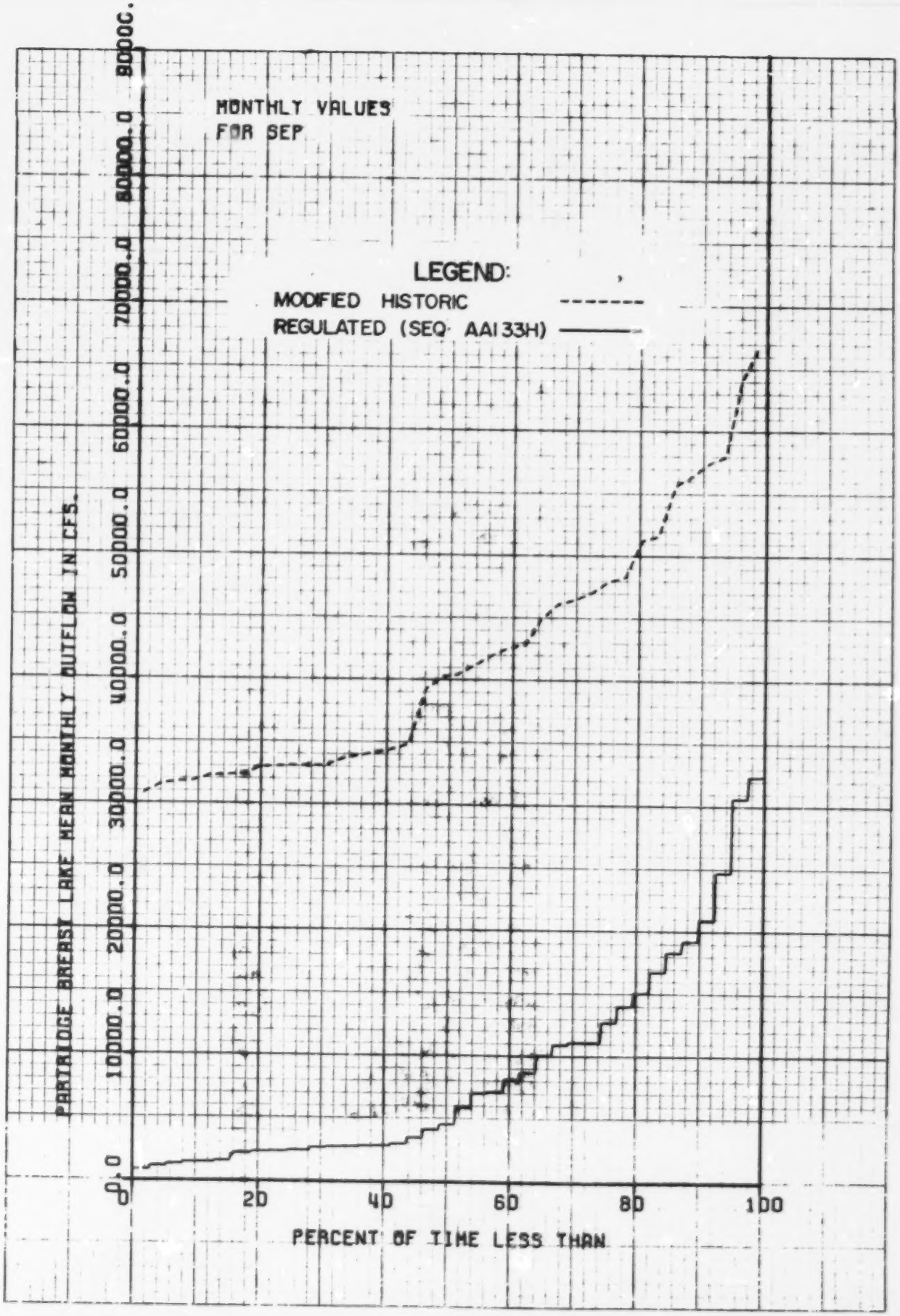

MONTHLY VALUES
FOR APR
LEGEND:
MODFED HISTORIC
REGULATED (SEQ AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

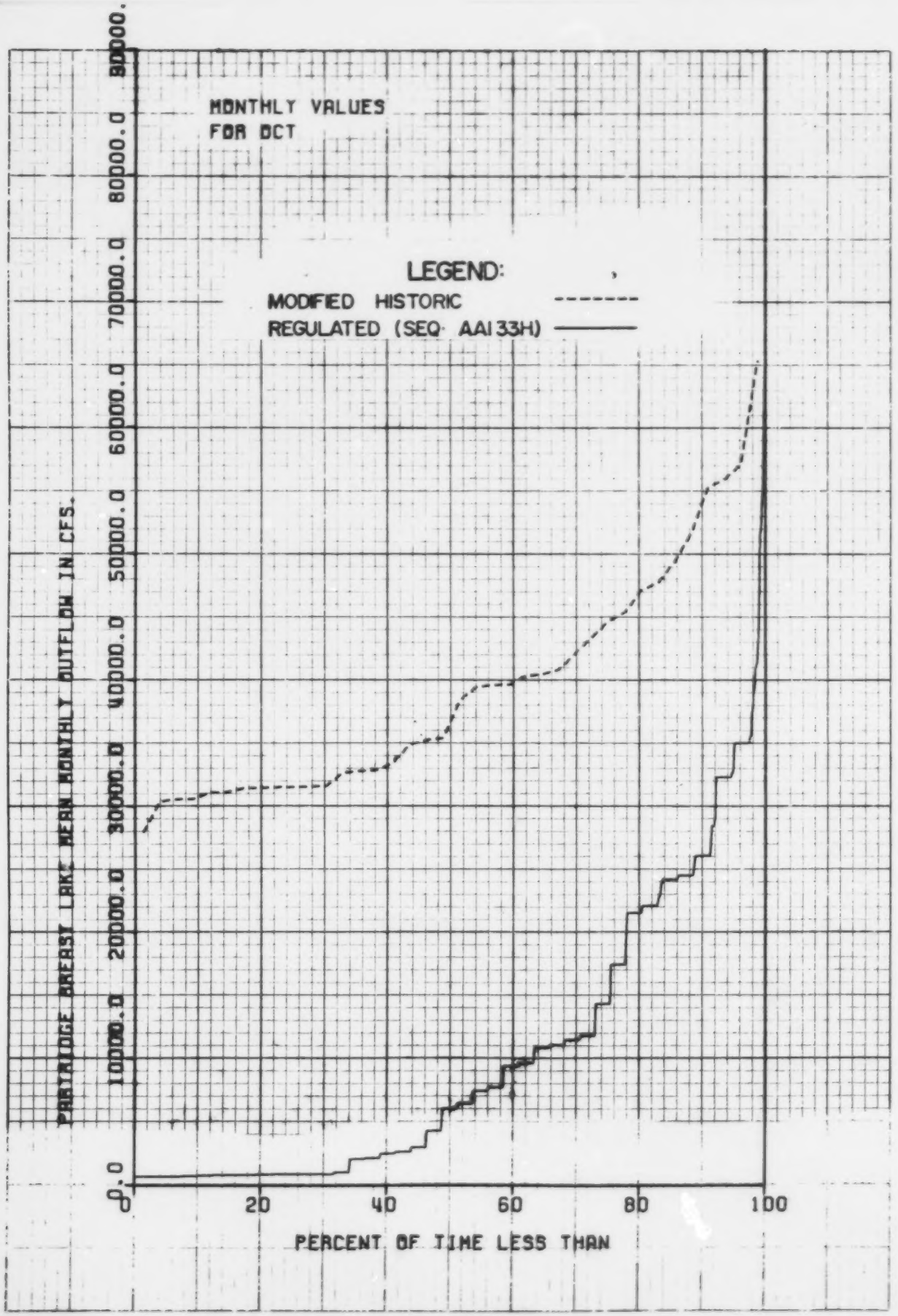

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

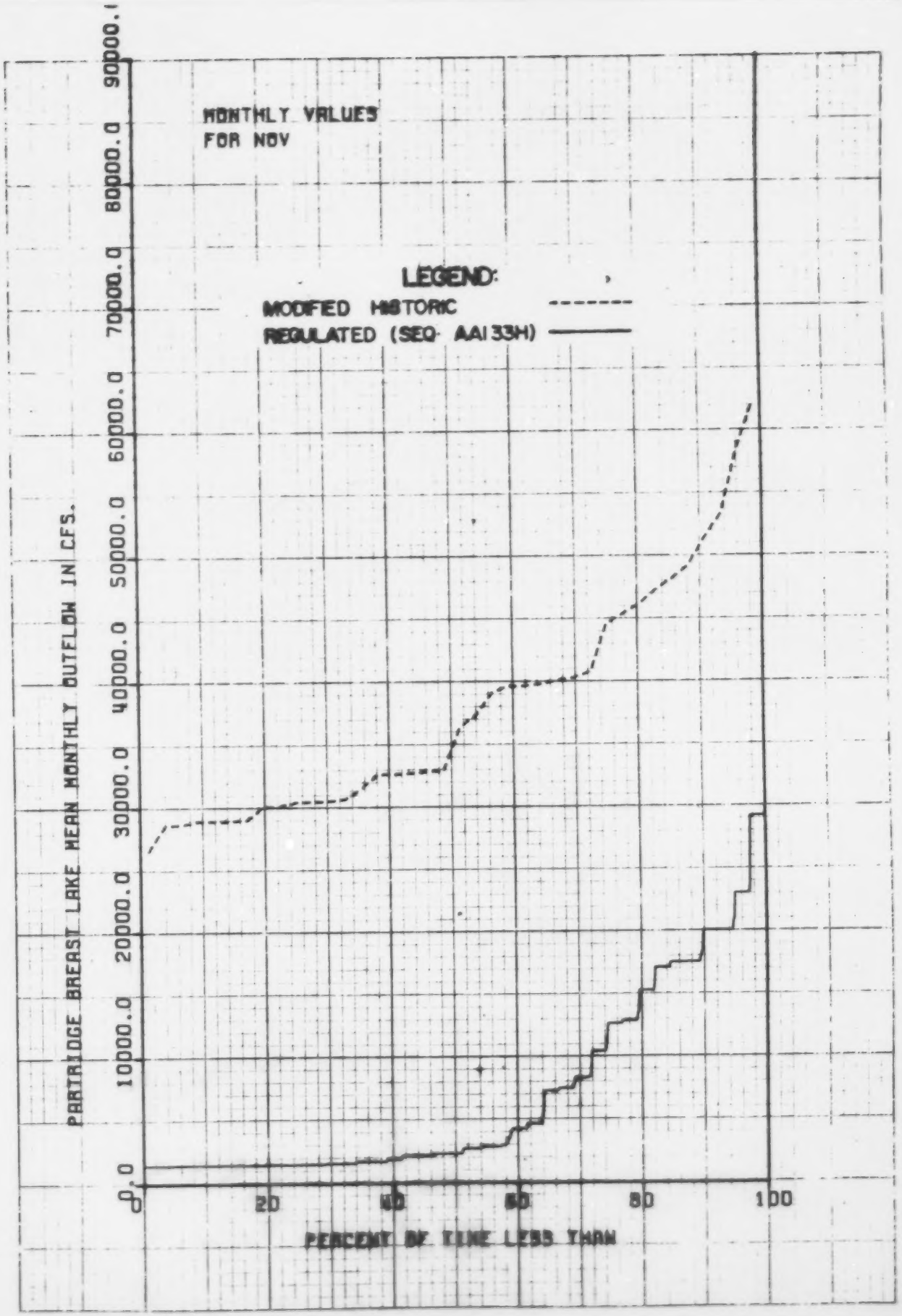

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

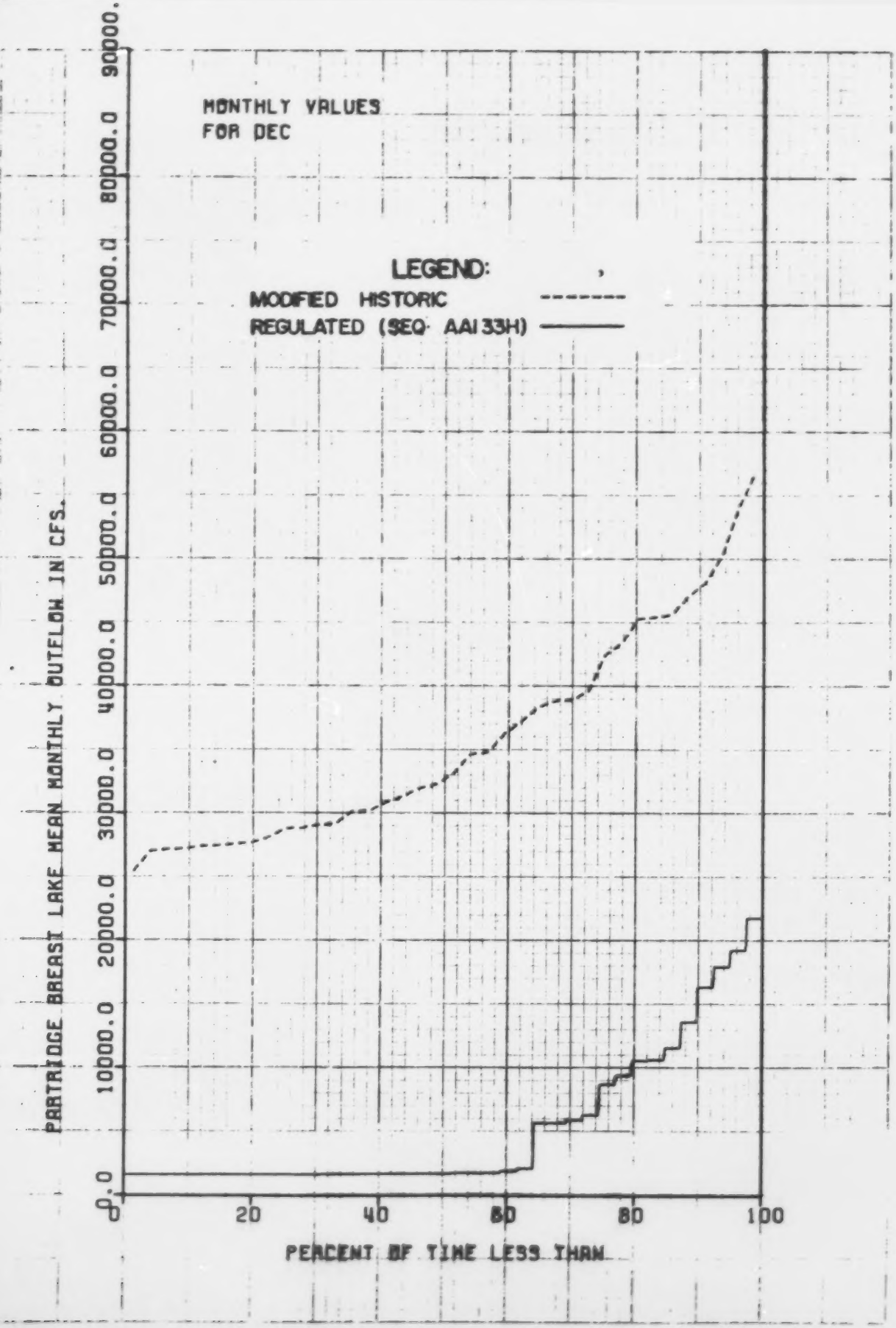

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
PRINEVILLE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
80000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
PARTRIDGE BREAST LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

Northern Indian Lake Levels

NORTHERN INDIAN LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	3	76	0	74	8	71	37	53	55	18	39	3	45	0	61	18	47	29	16	57	8	71	5	84
1 - 2	0	18	0	26	0	21	0	11	24	0	21	0	32	0	13	3	0	16	3	16	5	16	0	11
2 - 4	0	3	0	0	0	0	0	0	3	0	32	0	21	0	5	0	3	5	3	5	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	5	0	3	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

														ANNUAL
MINIMUM	770.70	770.30	770.21	769.98	769.96	771.04	771.85	772.60	772.64	771.76	771.22	770.83	769.96
AVERAGE	773.49	772.74	772.15	771.84	772.36	774.14	775.61	776.11	775.83	775.22	774.77	774.17	774.04
MAXIMUM	778.82	777.04	775.06	774.03	775.70	781.63	783.70	783.50	782.21	781.87	781.09	779.96	783.80

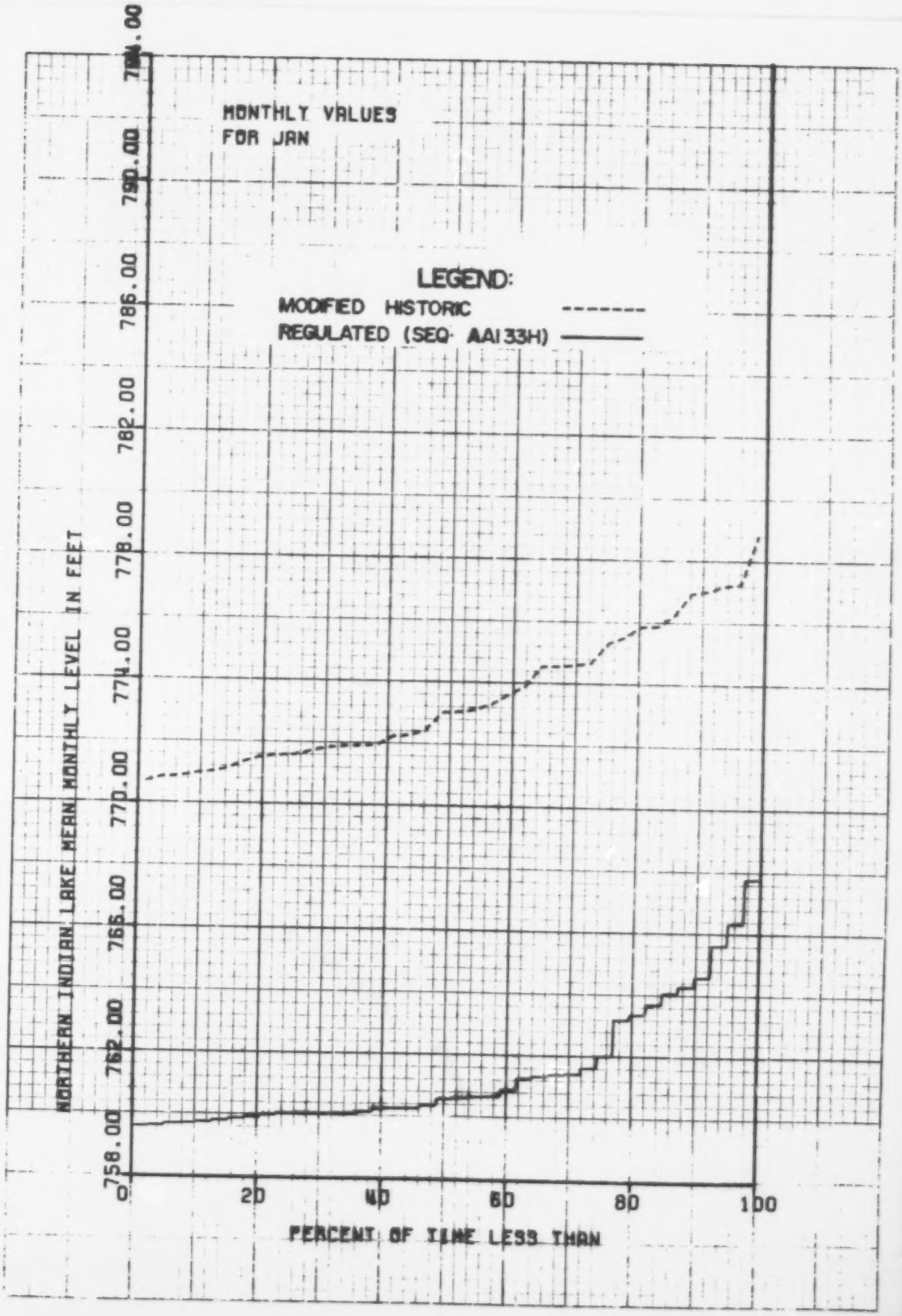
NORTHERN INDIAN LAKE - REGULATED CONDITIONS

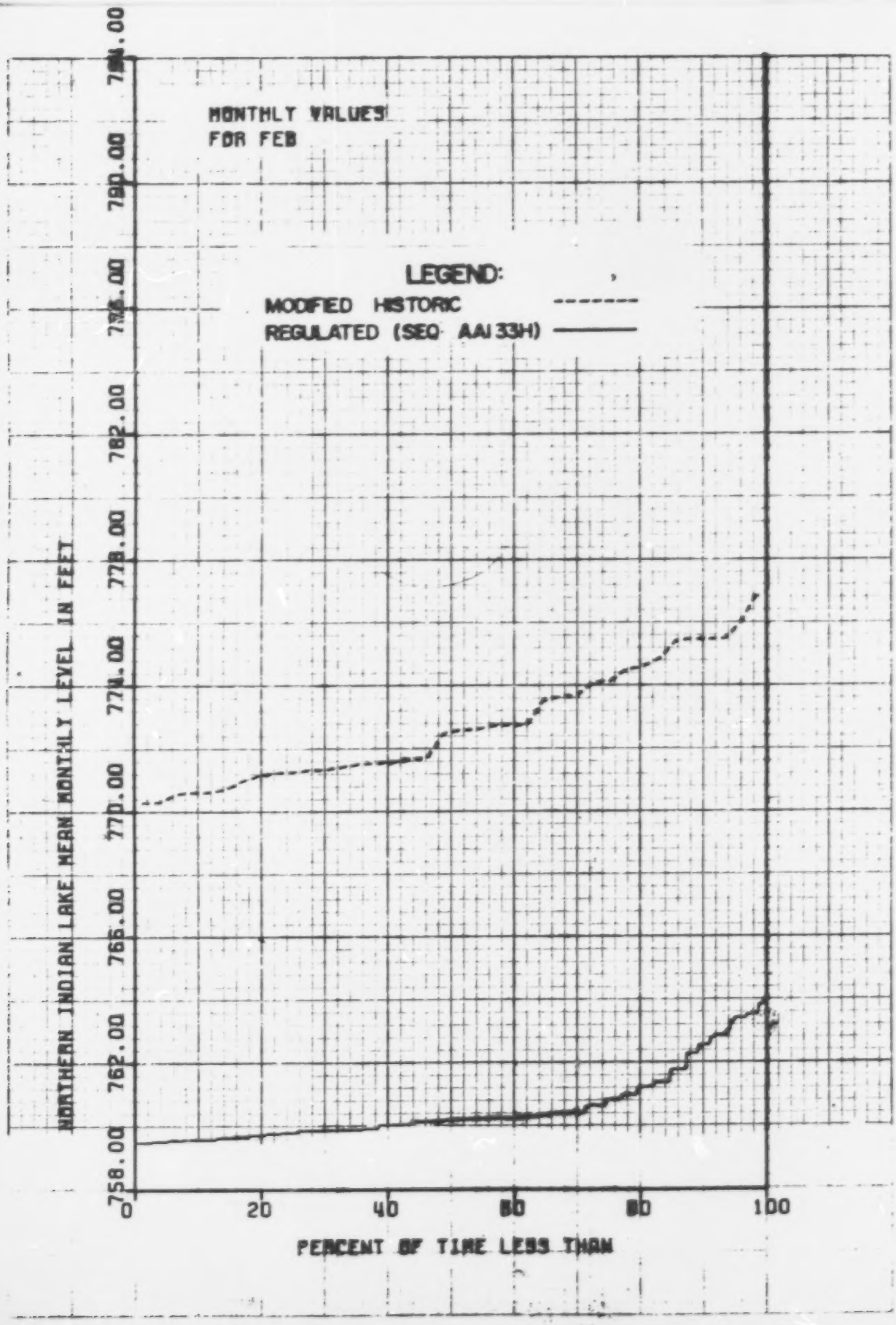
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

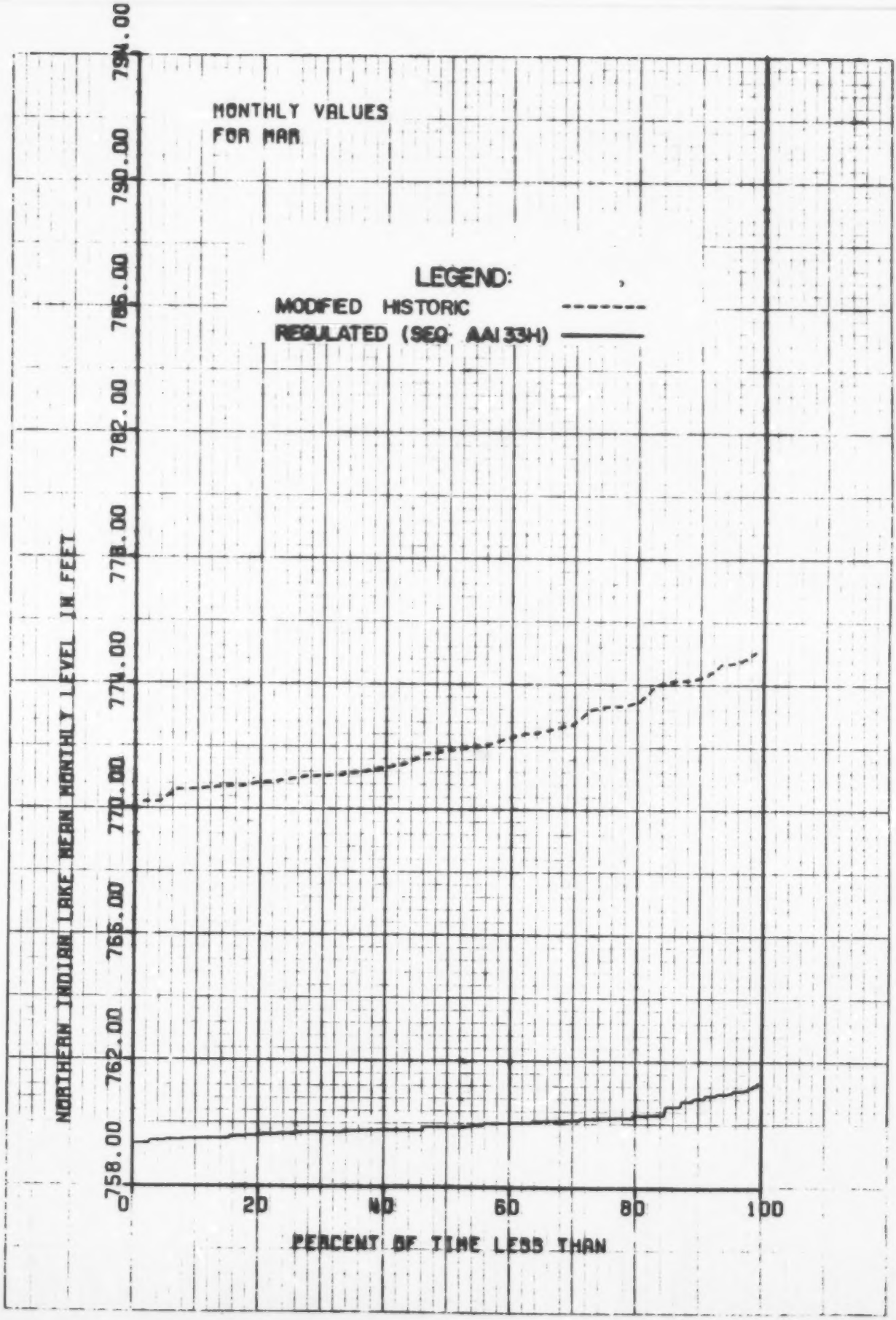
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	10	52	2	66	0	79	14	75	15	43	9	4	20	15	16	21	1	4	10	16	15	55	27	29
1 - 2	0	11	0	17	0	15	2	4	0	0	3	0	18	17	6	22	2	16	8	38	2	7	2	25
2 - 4	0	28	0	13	0	5	4	0	6	0	10	0	14	14	4	23	2	58	0	20	0	15	0	15
4 - 6	0	0	0	2	0	0	1	0	11	0	39	0	2	0	0	5	0	13	3	3	0	0	0	2
6 - 8	0	0	0	0	0	0	0	0	9	0	17	0	0	0	0	2	0	2	3	0	0	3	0	0
8 -	0	0	0	0	0	0	0	0	17	0	18	0	0	0	0	0	0	0	0	0	0	2	0	0

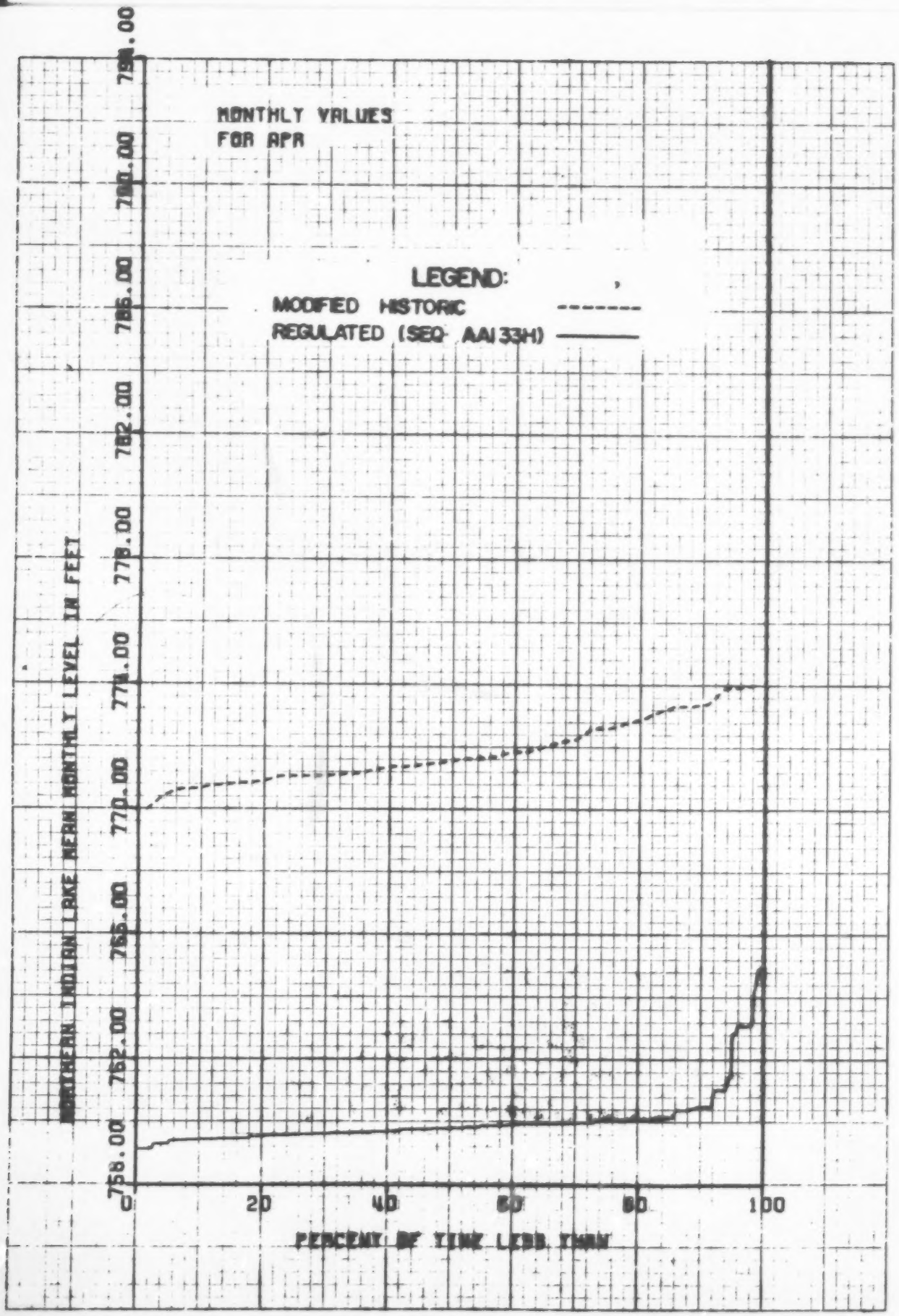
MEAN MONTHLY LEVELS IN FEET

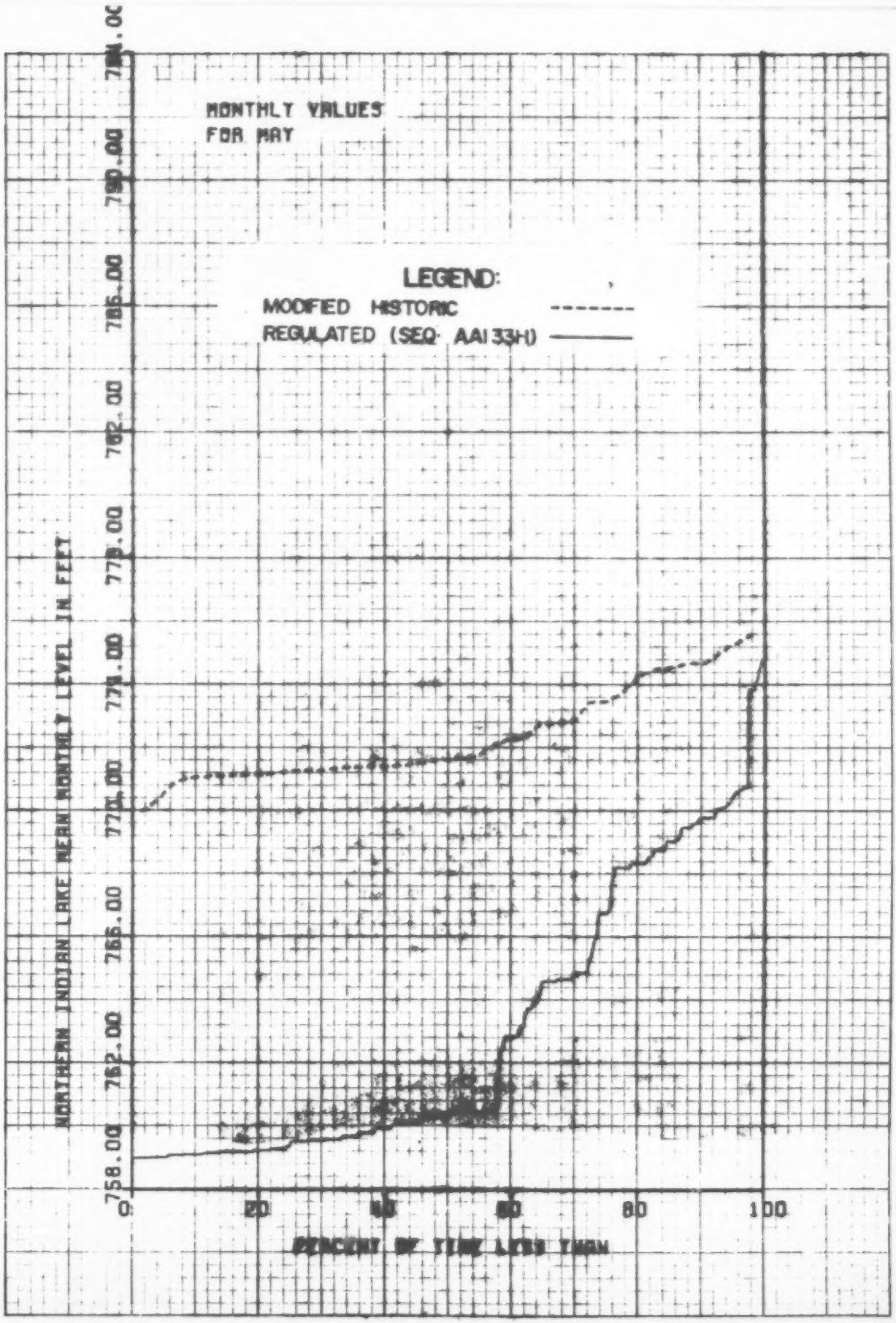
														ANNUAL
MINIMUM	759.57	759.46	759.31	759.10	758.95	758.76	759.36	759.91	759.25	759.32	759.35	759.57	758.76
AVERAGE	761.39	760.51	759.97	759.99	762.92	768.58	768.73	767.51	764.87	764.45	763.43	762.48	763.73
MAXIMUM	767.75	763.92	761.31	764.92	774.72	782.68	779.16	775.95	773.72	781.40	773.88	770.26	782.68

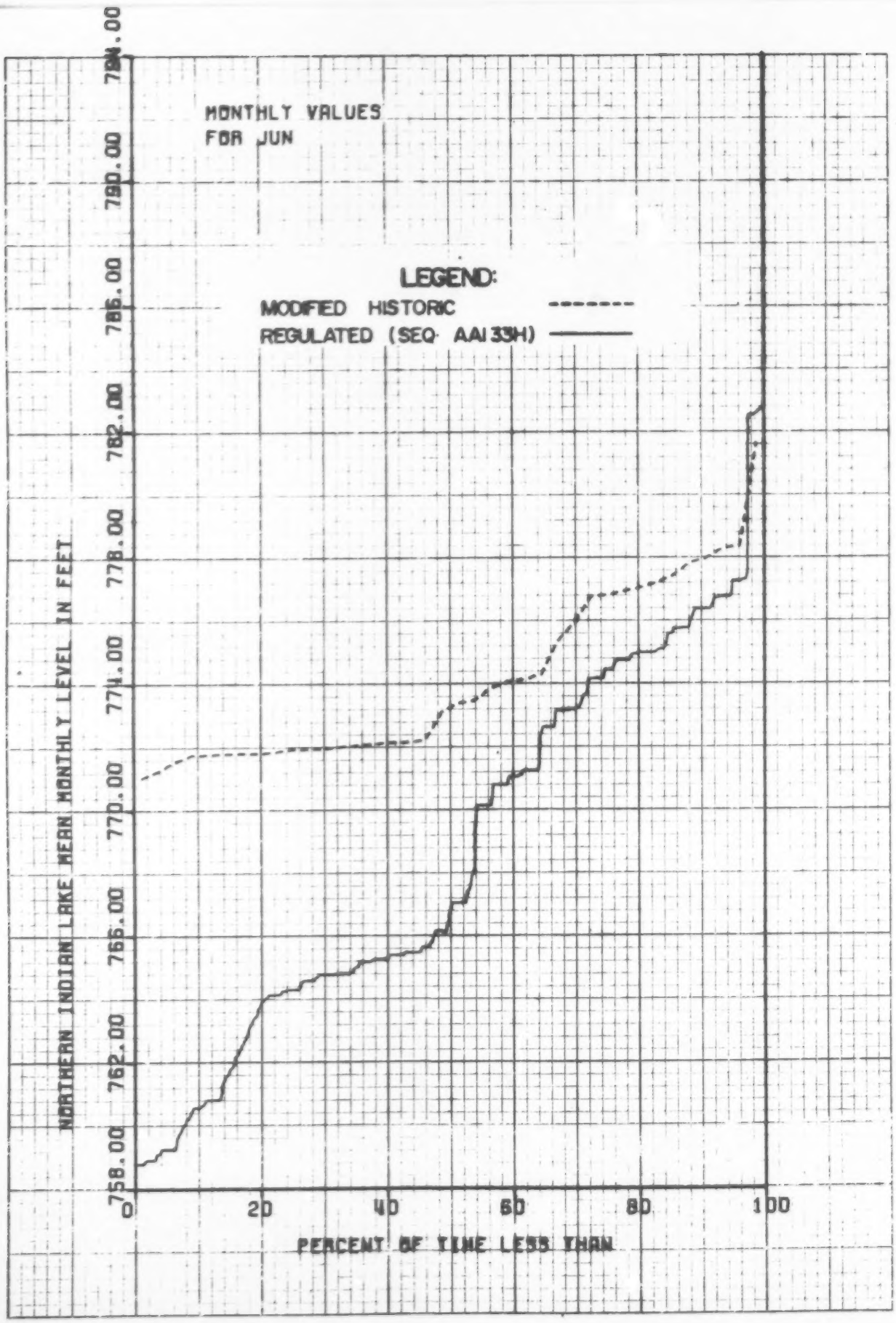

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
794.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

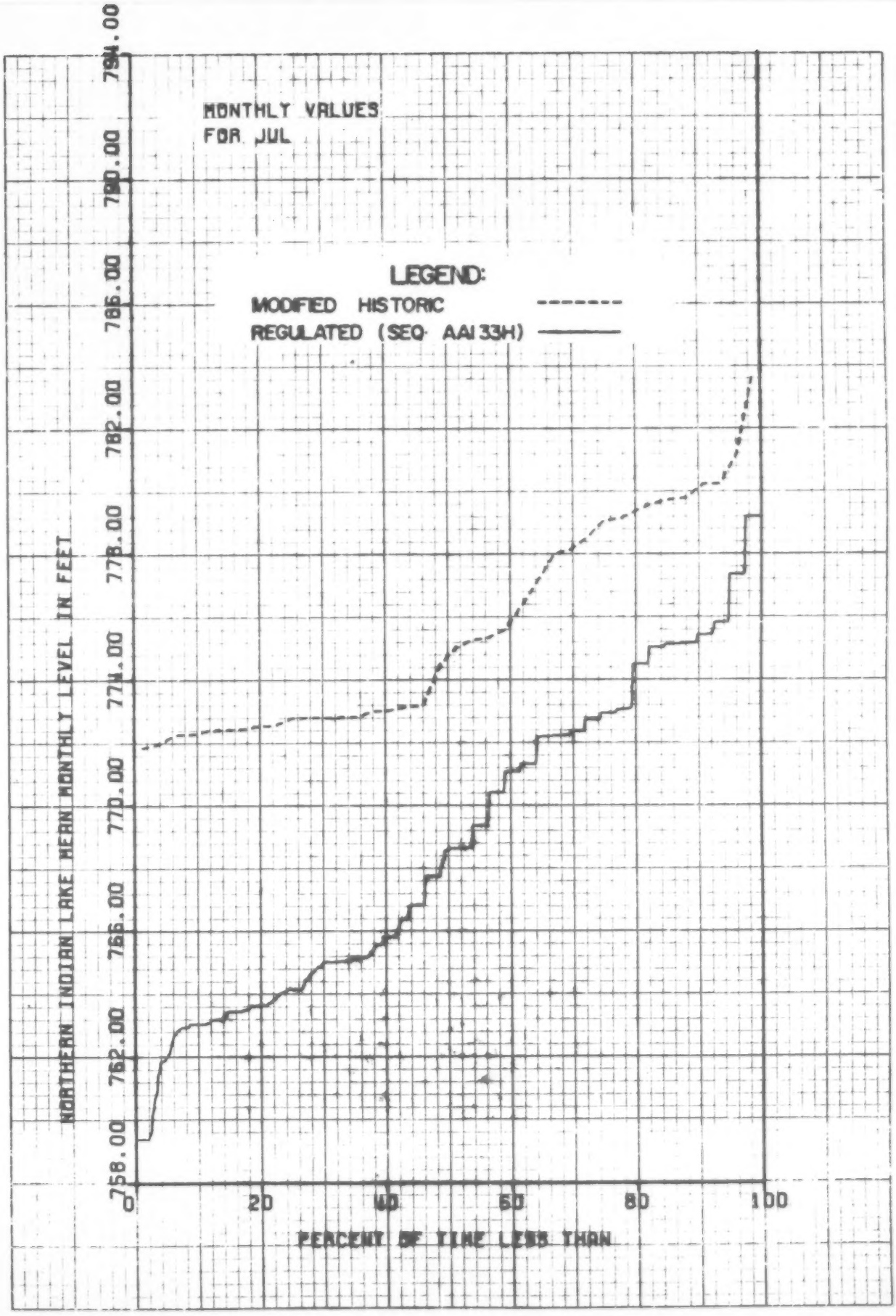

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
790.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

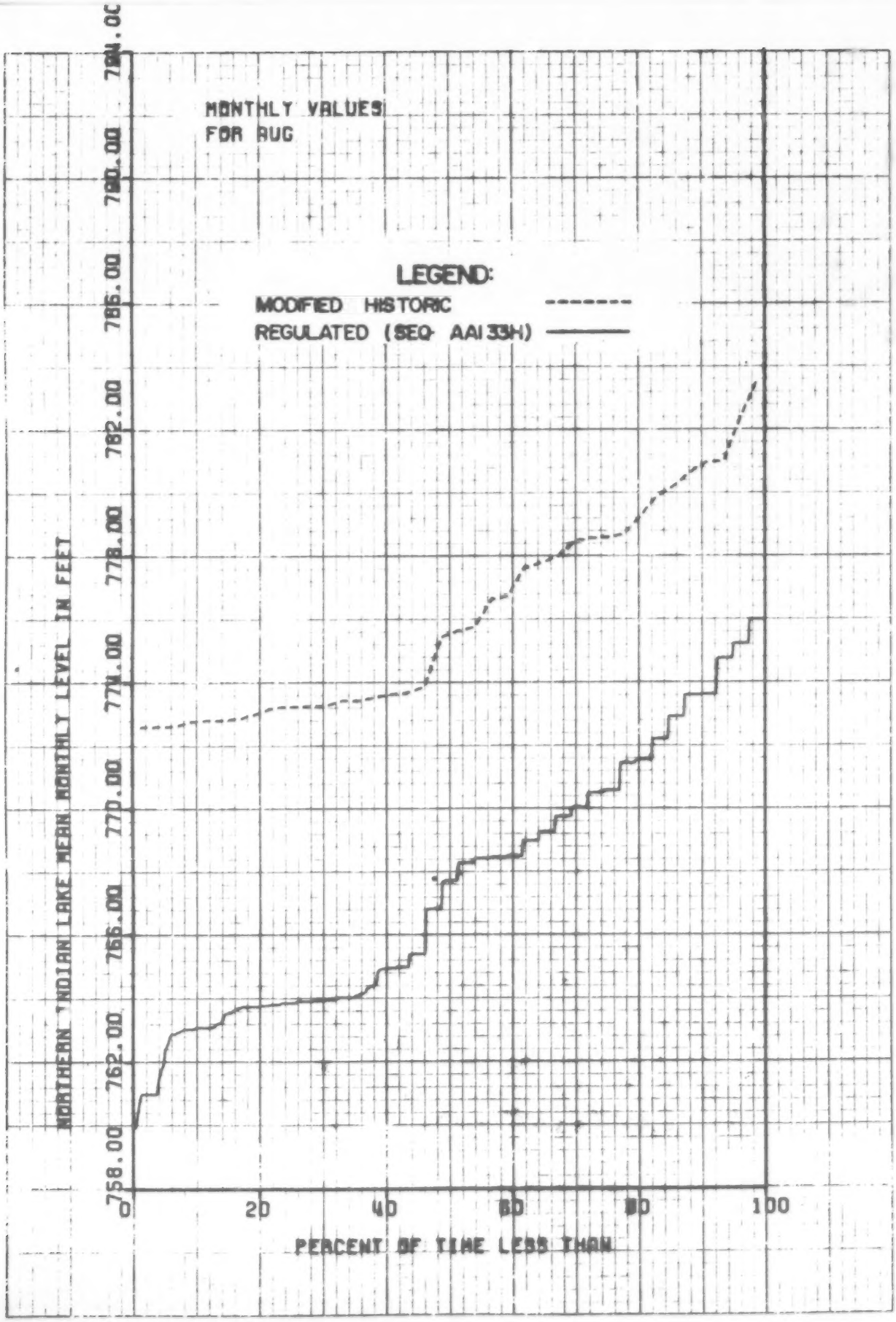

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
794.00
790.00
786.00
782.00
778.00
774.00
770.00
766.00
762.00
758.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

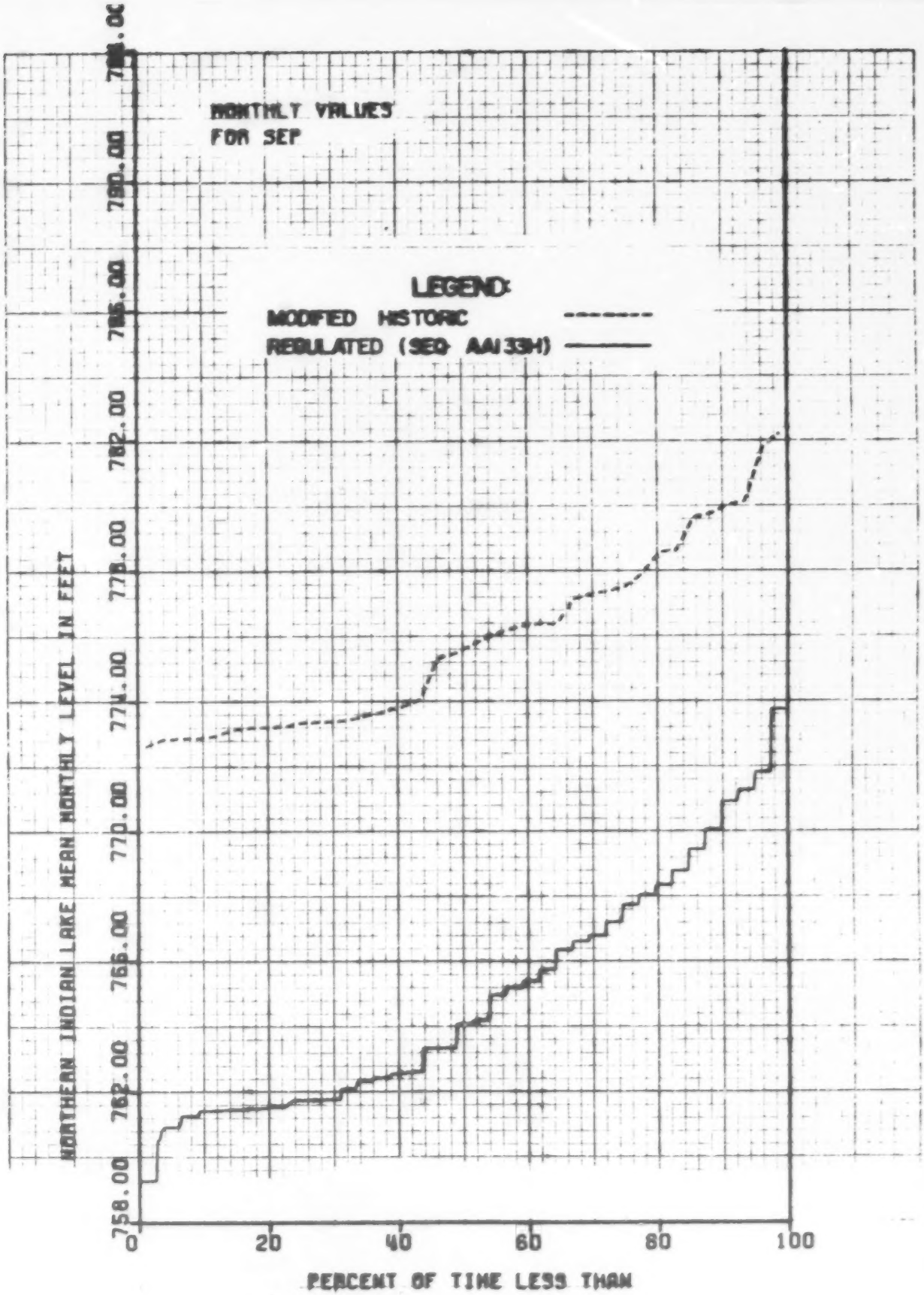

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

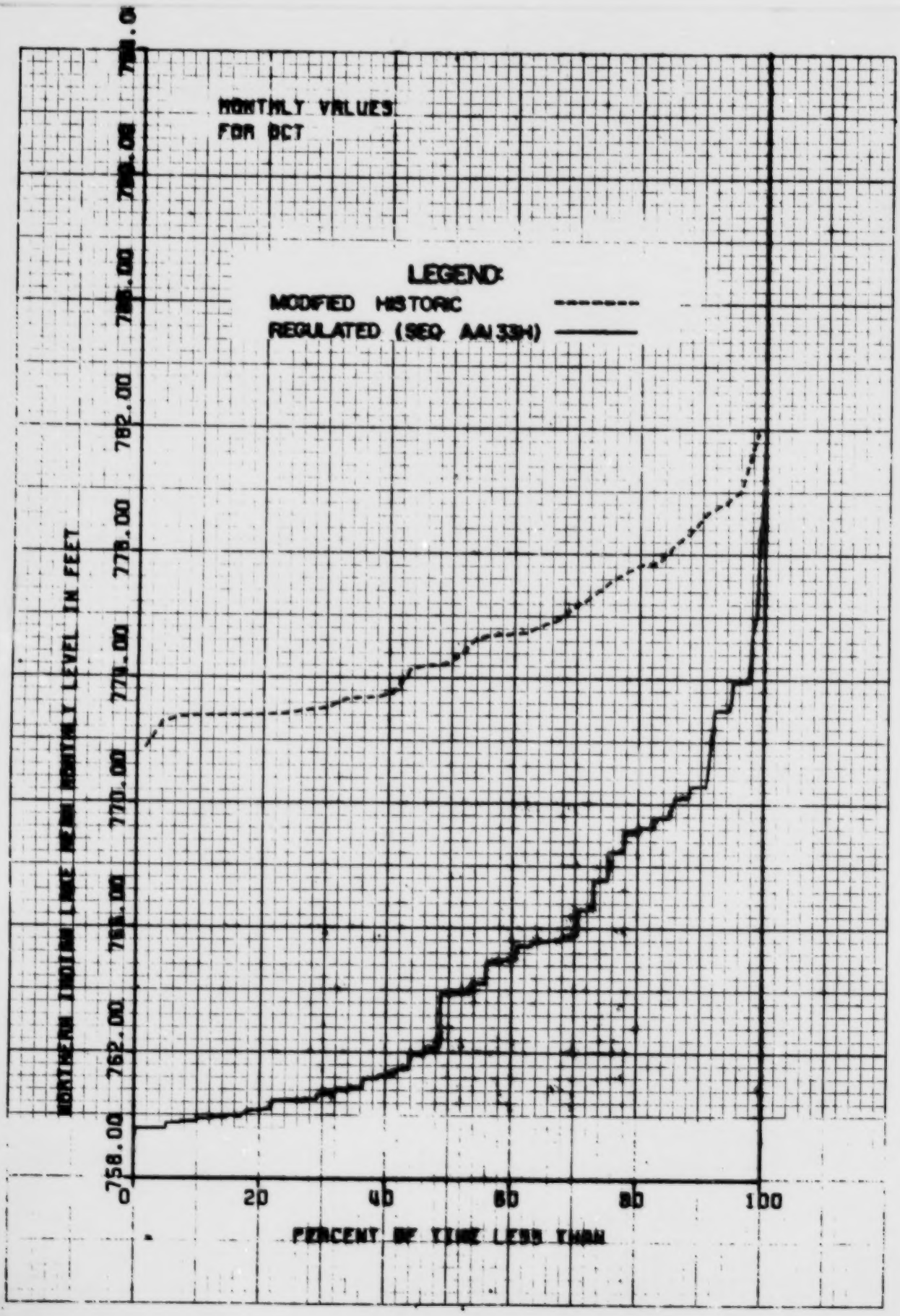

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

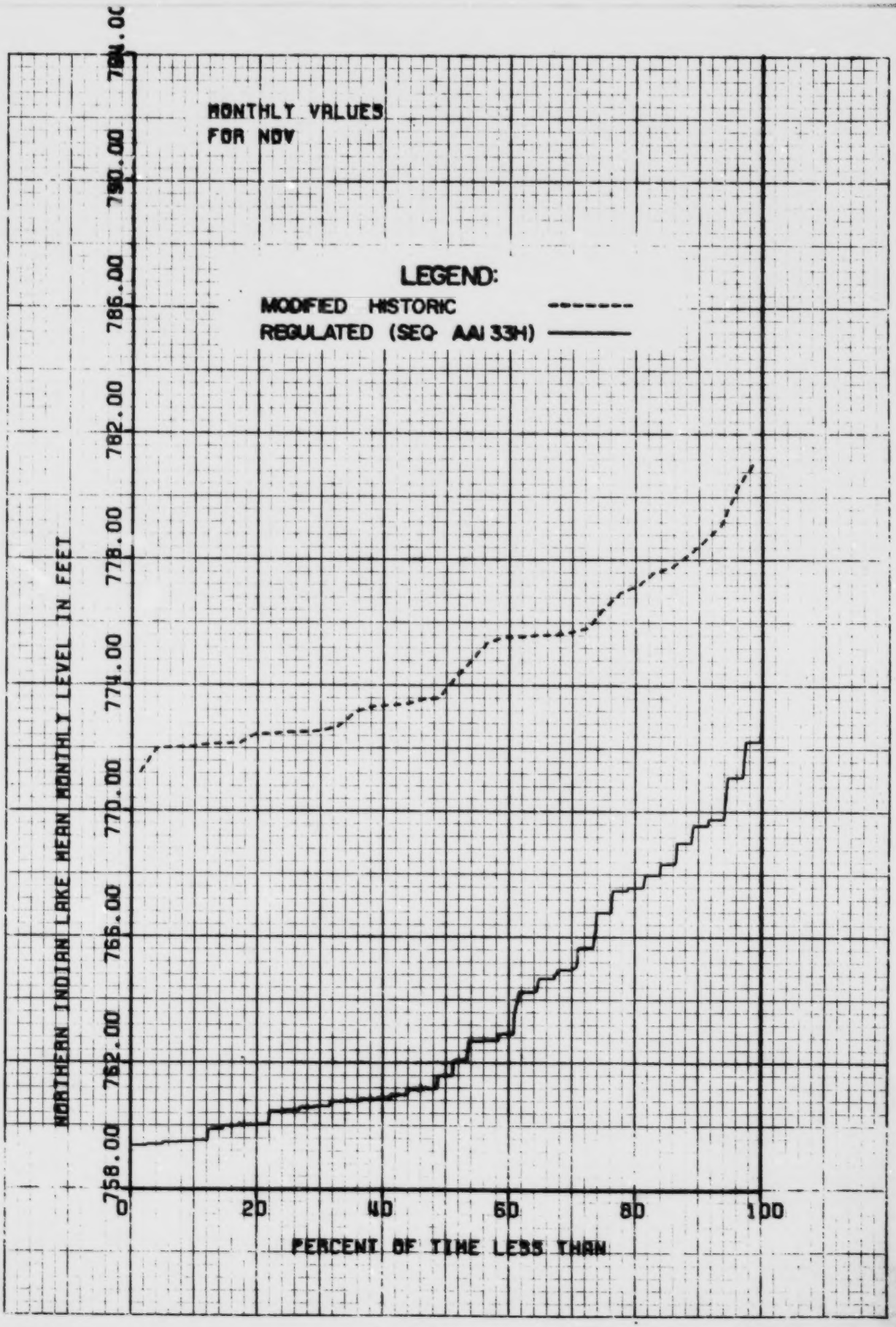

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
794.00
790.00
786.00
782.00
778.00
774.00
770.00
766.00
762.00
758.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

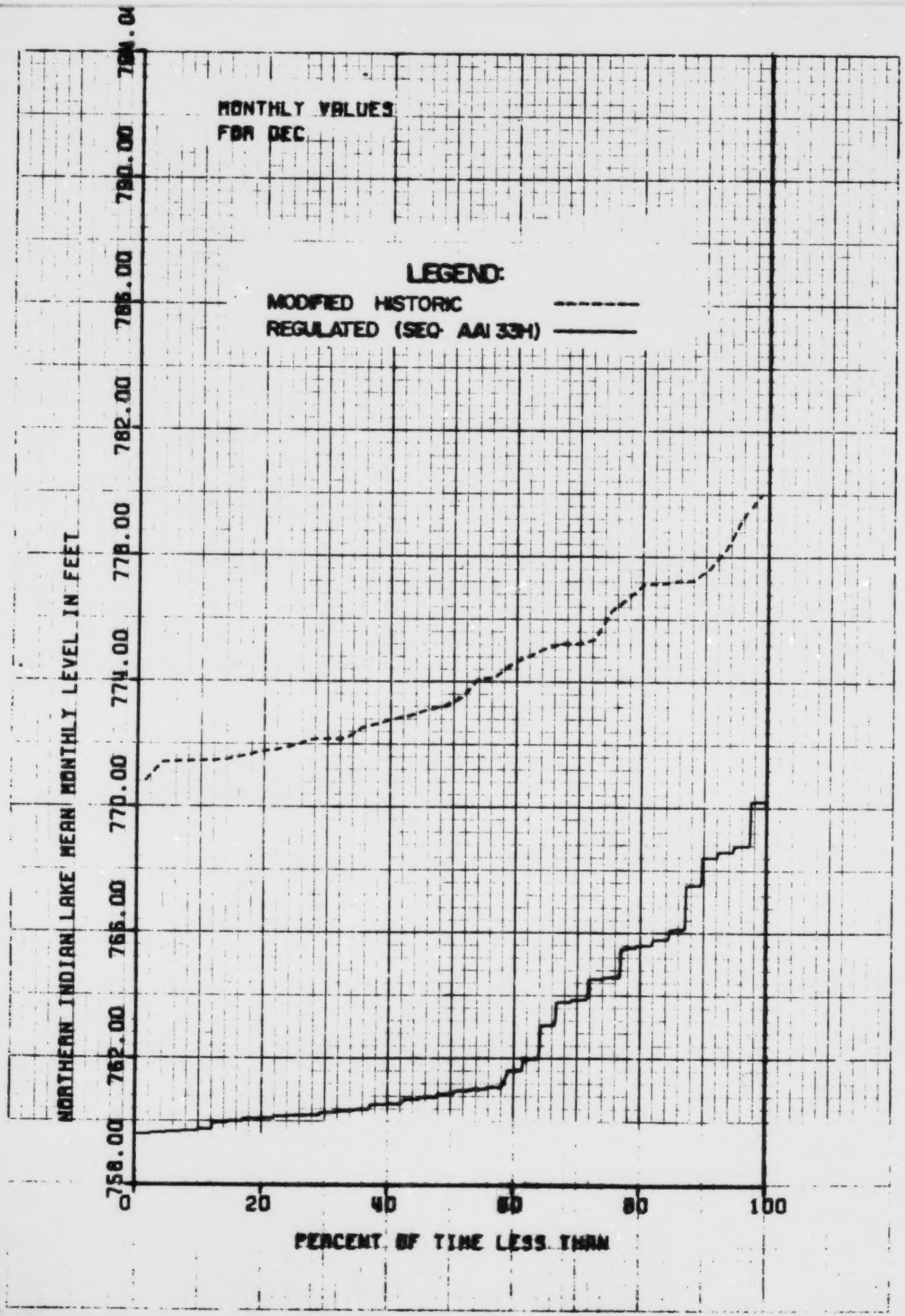

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
794.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
794.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
800.00
790.00
780.00
770.00
760.00
750.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AA1334)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI 33H)
NORTHERN INDIAN LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI 33H)
NORTHERN INDIANA LAKE MEAN MONTHLY LEVEL IN FEET
758.00
762.00
766.00
770.00
774.00
778.00
782.00
786.00
790.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

NORTHERN INDIAN LAKE
OUTFLOWS

NORTHERN INDIAN LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	3	84	0	87	8	84	37	63	71	18	50	3	61	0	66	18	45	32	11	62	8	82	5	87
5 - 10	0	13	0	13	0	8	0	0	11	0	21	0	18	0	13	3	3	21	3	22	5	5	0	8
10 - 20	0	0	0	0	0	0	0	0	0	0	24	0	21	0	0	0	0	0	3	0	0	0	0	0
20 - 30	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

MINIMUM	26,010	24,780	24,530	23,790	23,750	27,030	29,490	31,790	31,880	29,210	27,560	26,400	ANNUAL 23,750
AVERAGE	35,039	32,449	30,484	29,472	31,195	37,460	43,051	44,803	43,498	41,153	39,557	37,442	37,134
MAXIMUM	54,730	47,460	40,000	36,190	42,430	67,550	77,730	76,710	70,120	68,550	65,010	59,920	77,730

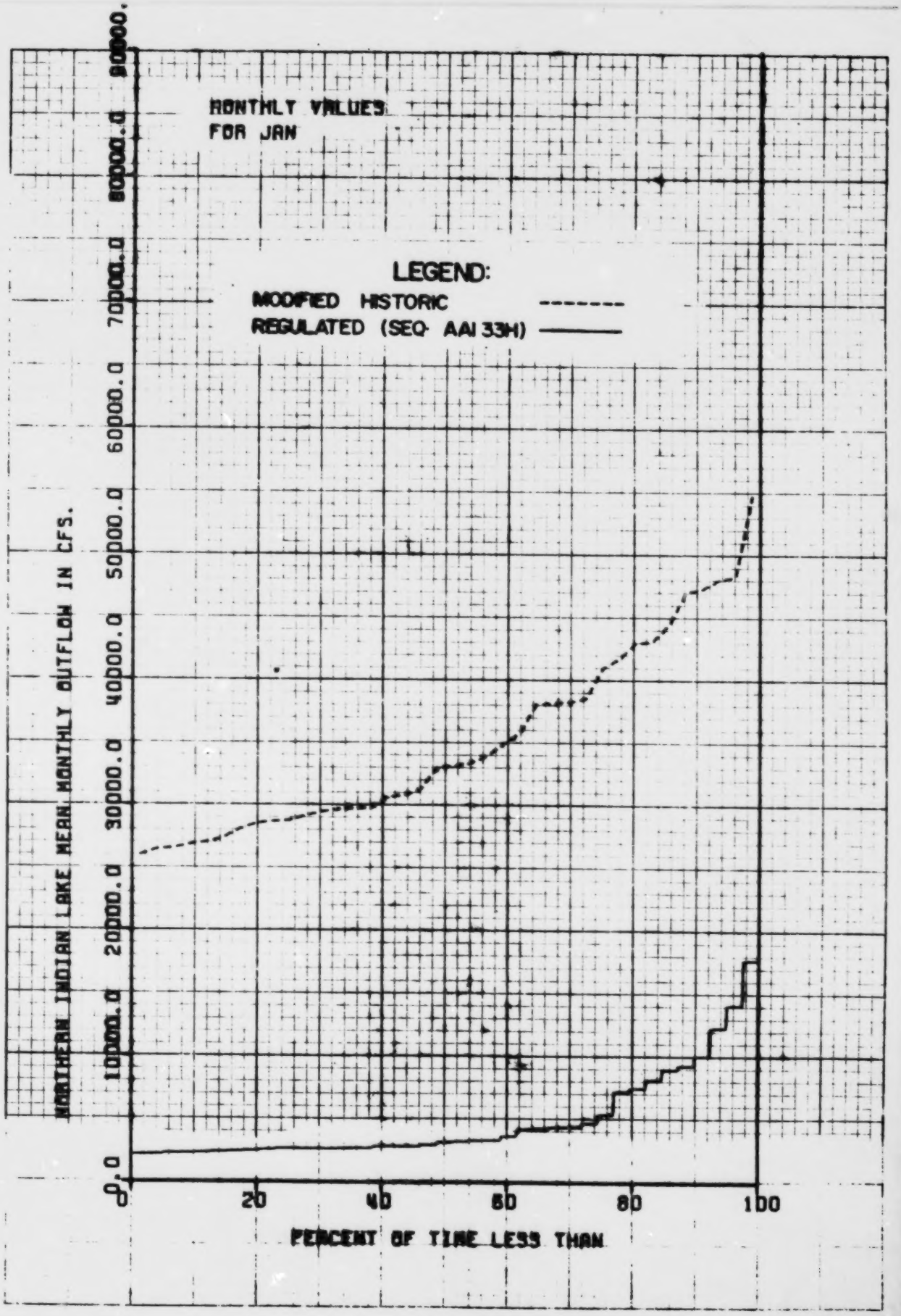
NORTHERN INDIAN LAKE - REGULATED CONDITIONS

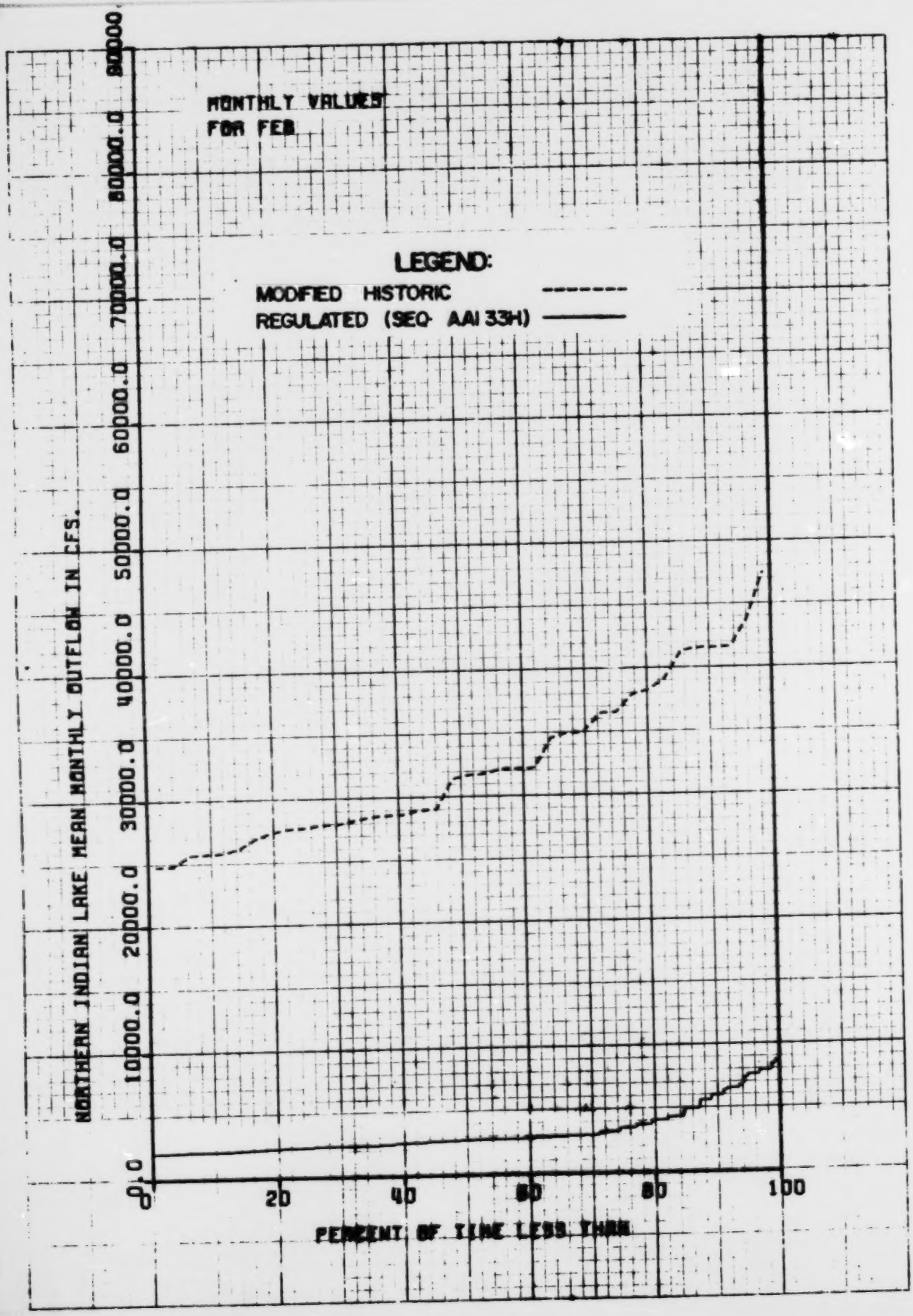
AVERAGE FLOW FLUCTUATIONS IN PERCENT

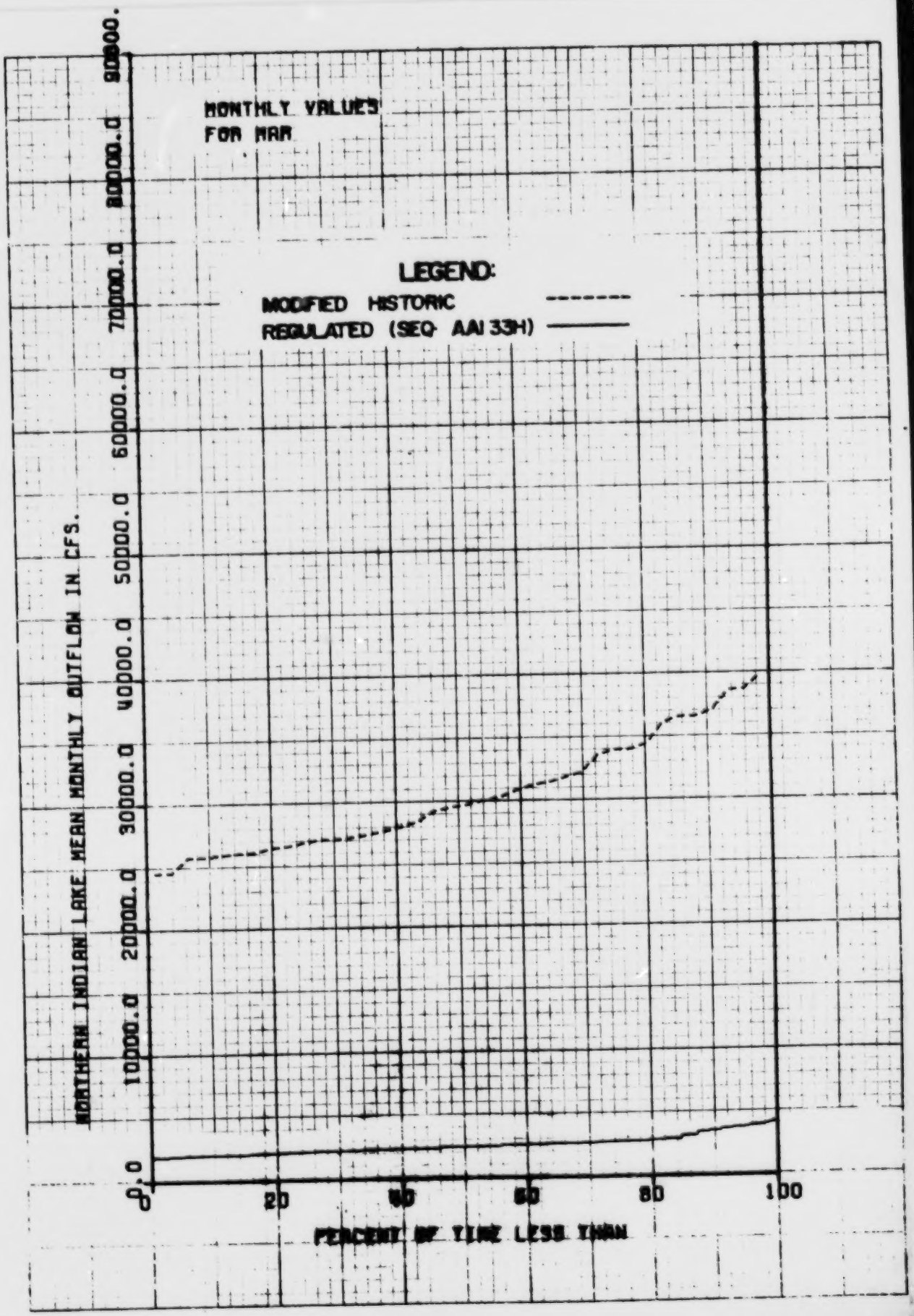
RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	10	72	2	89	0	100	20	79	19	43	15	4	45	29	21	43	4	40	18	64	18	70	29	56
5 - 10	0	18	0	8	0	0	2	0	12	0	32	0	8	16	2	16	2	28	0	10	0	7	0	11
10 - 20	0	0	0	0	0	0	0	0	19	0	19	0	0	2	0	18	0	23	5	3	0	2	0	4
20 - 30	0	0	0	0	0	0	0	0	5	0	21	0	0	0	0	0	0	2	0	0	0	3	0	0
30 - 40	0	0	0	0	0	0	0	0	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

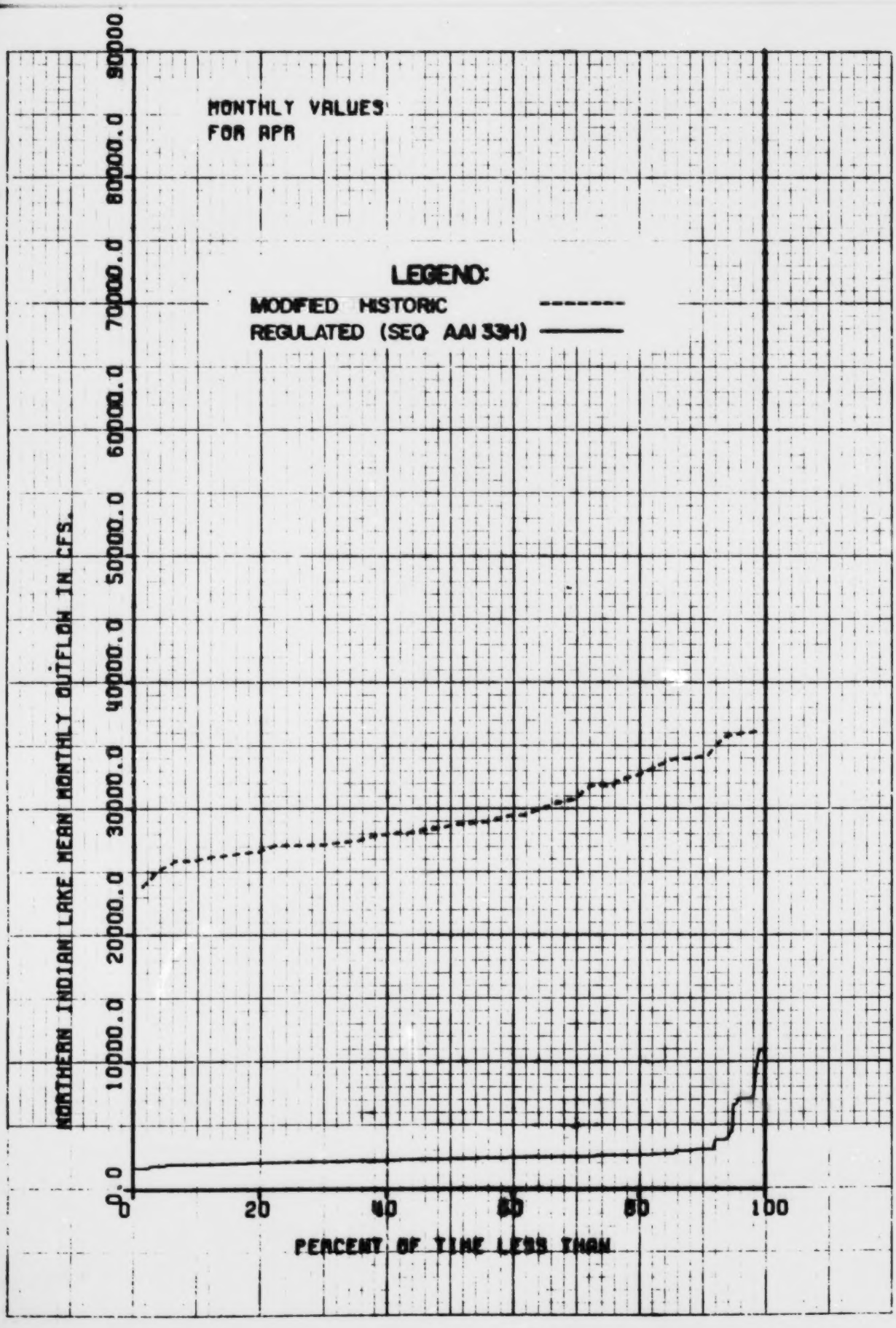
MEAN MONTHLY FLOWS IN CFS.

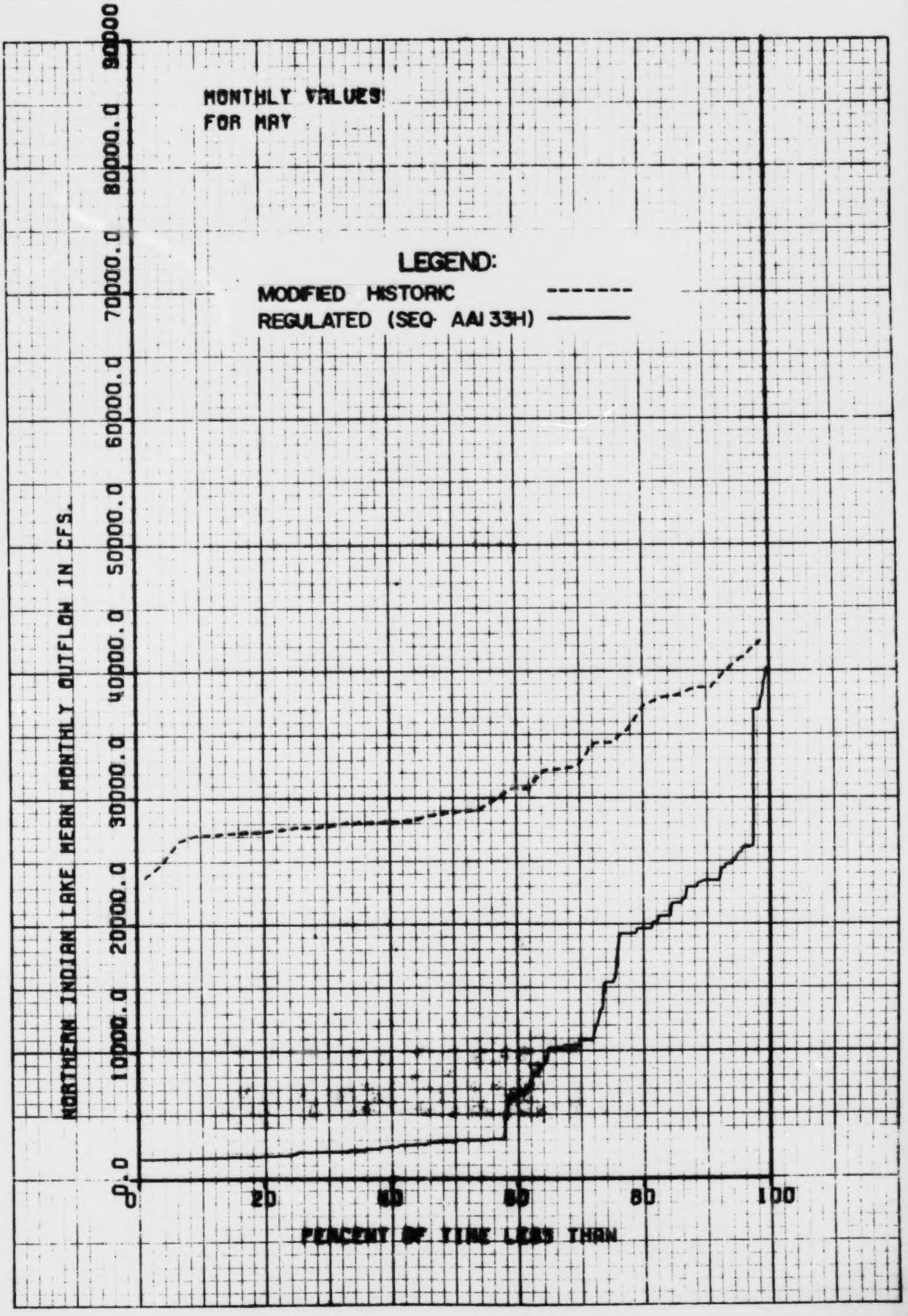
MINIMUM	2,070	1,970	1,820	1,600	1,490	1,350	1,860	2,410	1,780	1,830	1,850	2,070	ANNUAL 1,350
AVERAGE	4,731	3,234	2,508	2,602	8,792	22,659	21,975	18,132	11,800	11,589	9,081	6,923	10,336
MAXIMUM	17,640	8,670	4,170	10,910	40,120	72,580	56,280	43,310	35,280	66,370	36,200	24,630	72,580

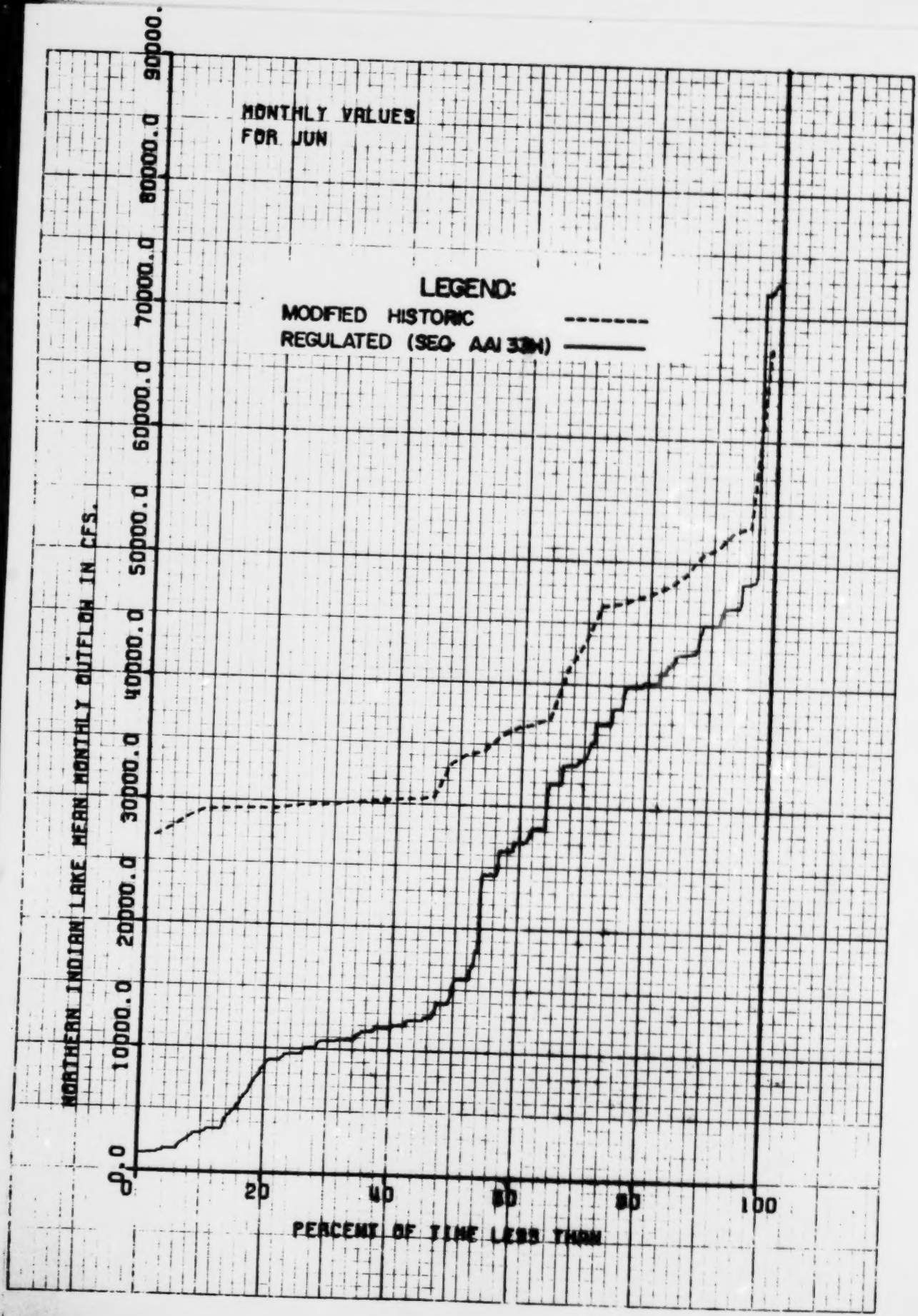

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
NORTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

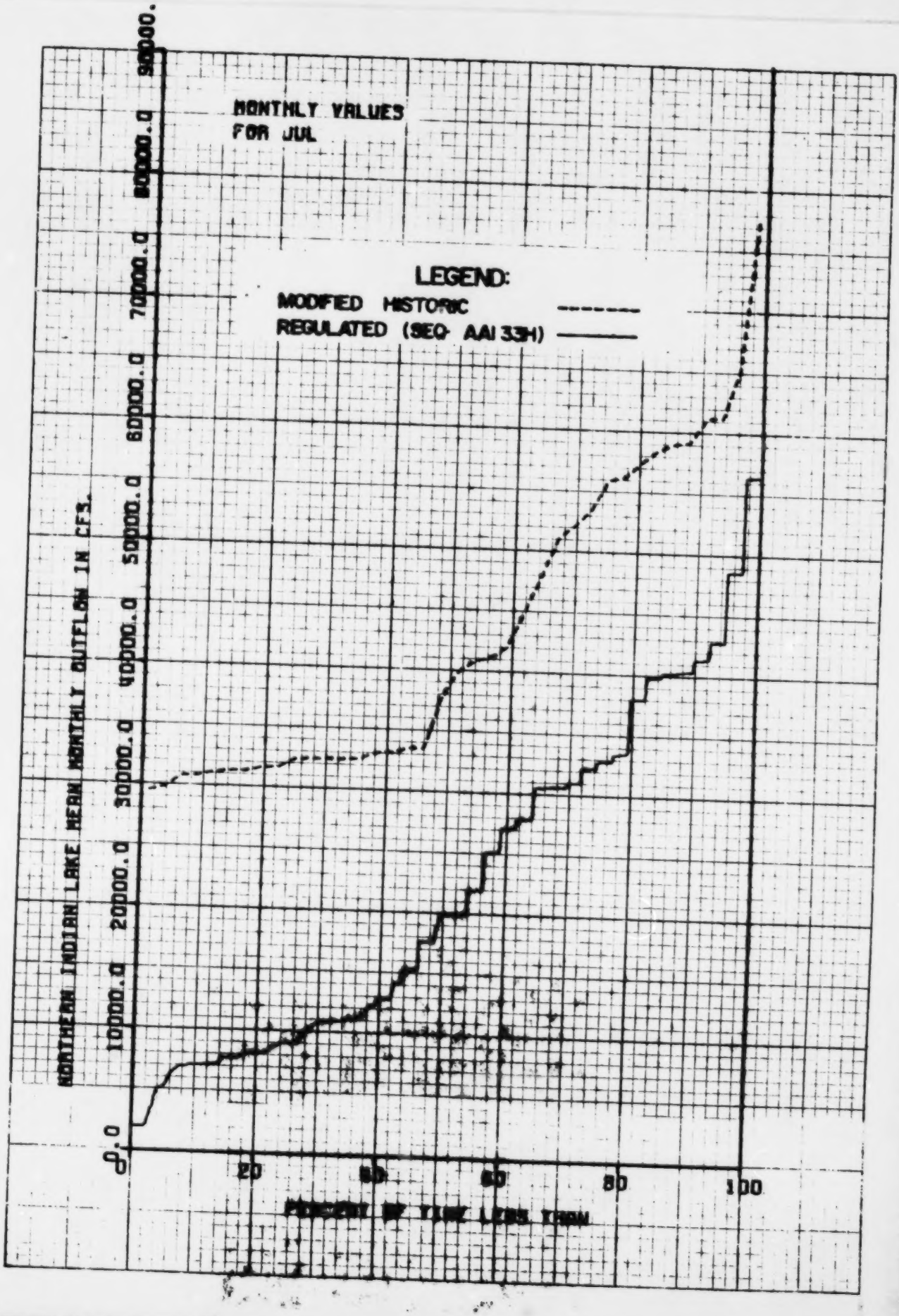

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

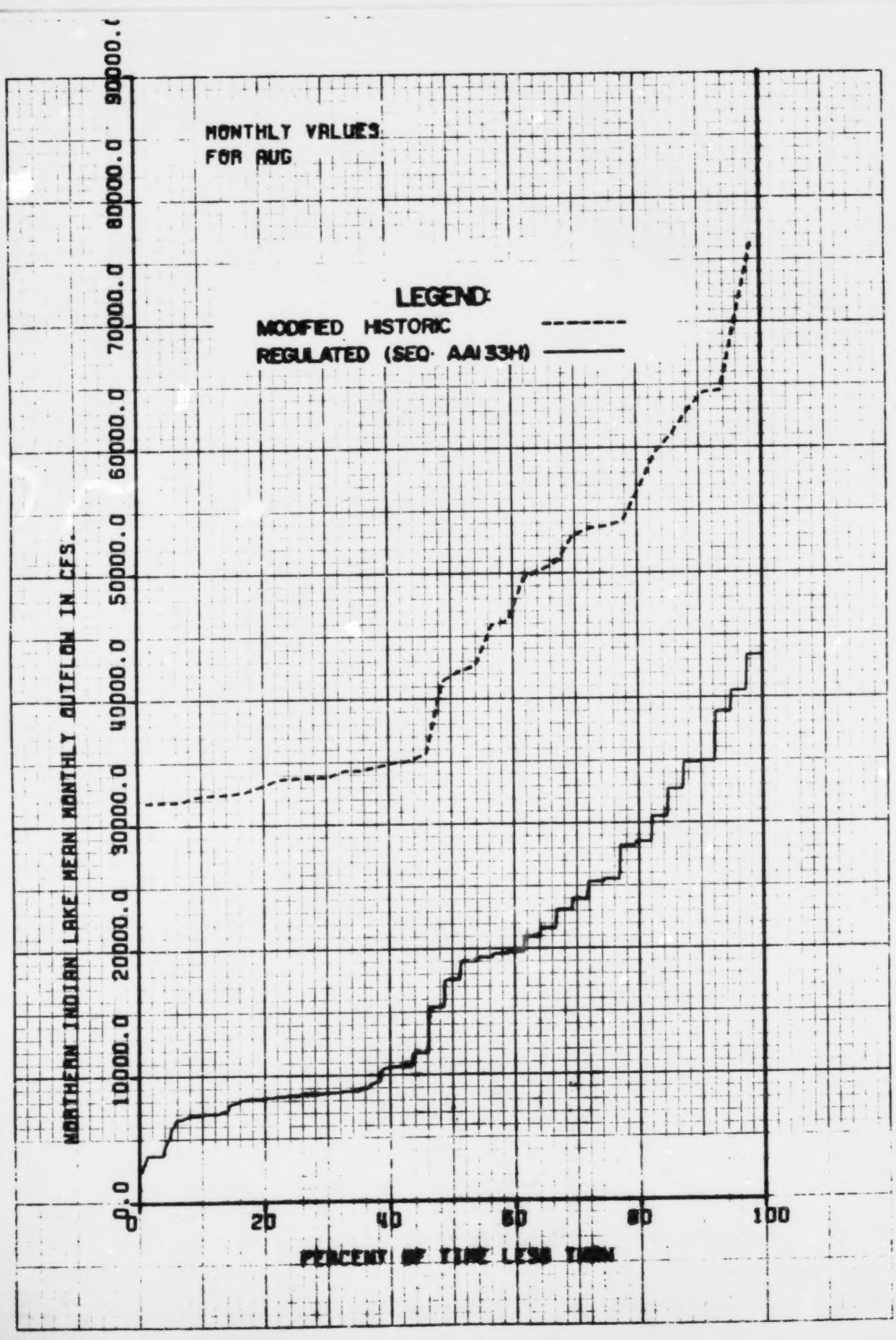

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

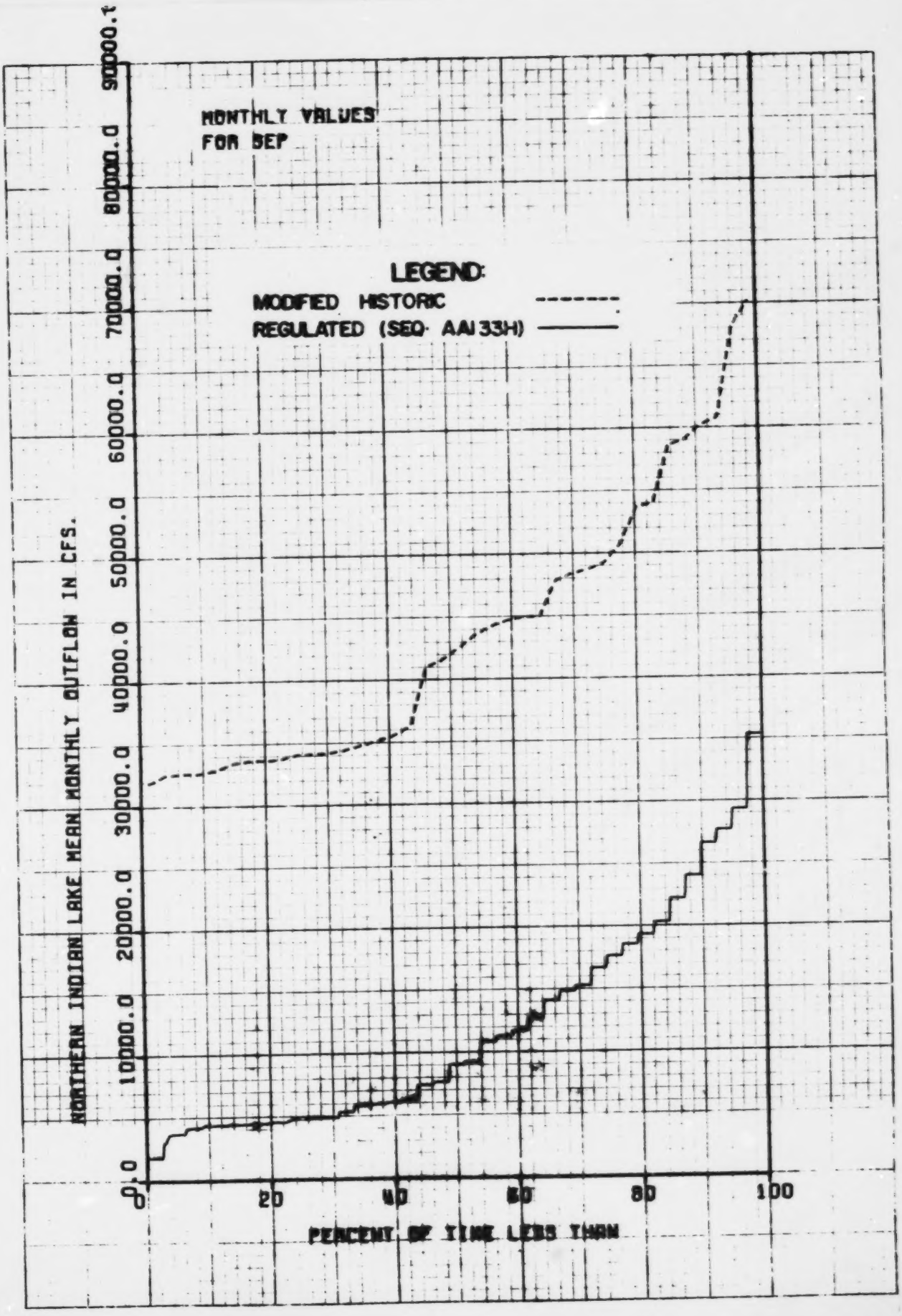

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

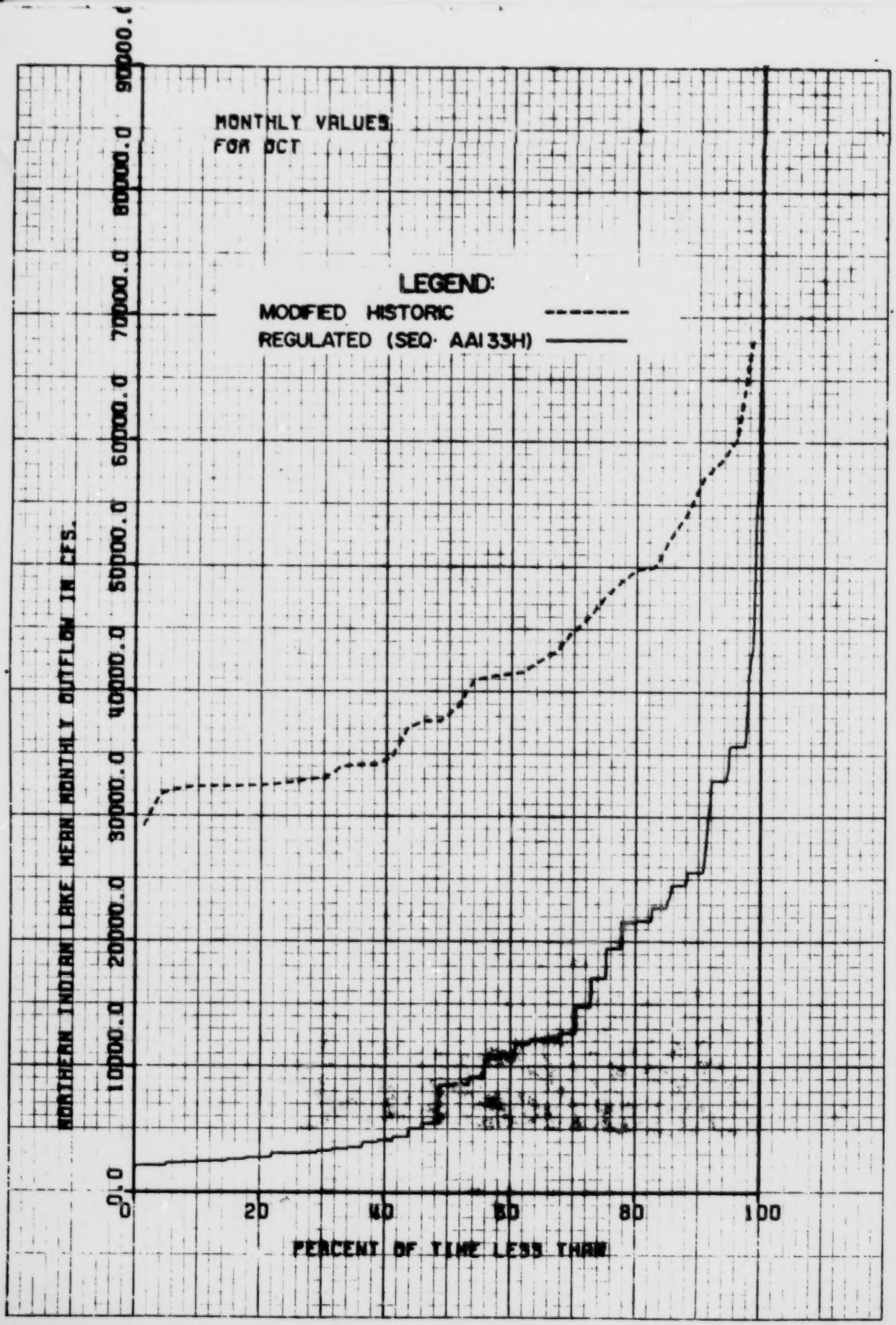

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

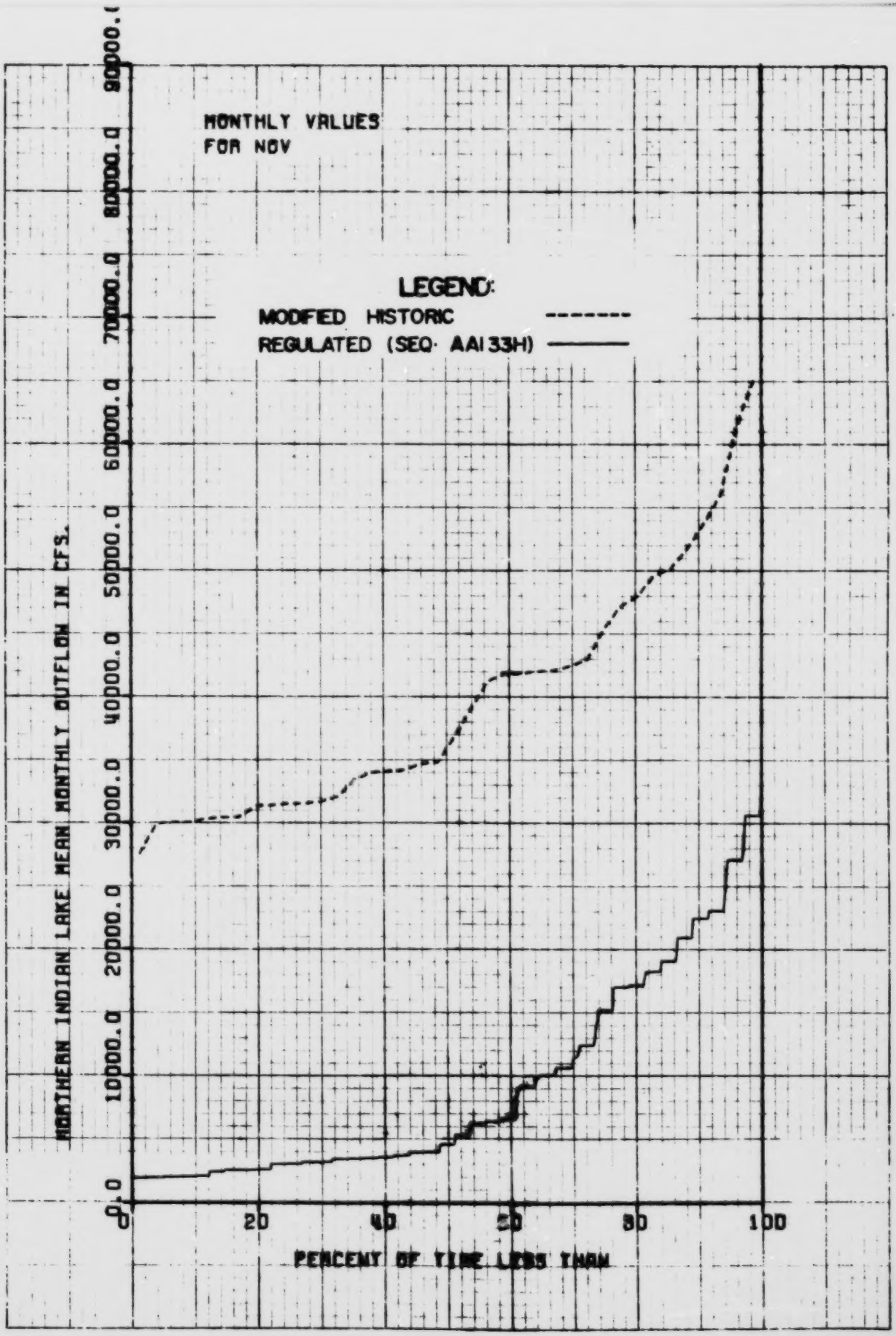

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33N)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
40
60
80
100
PERCENT OF TIME LESS THAN

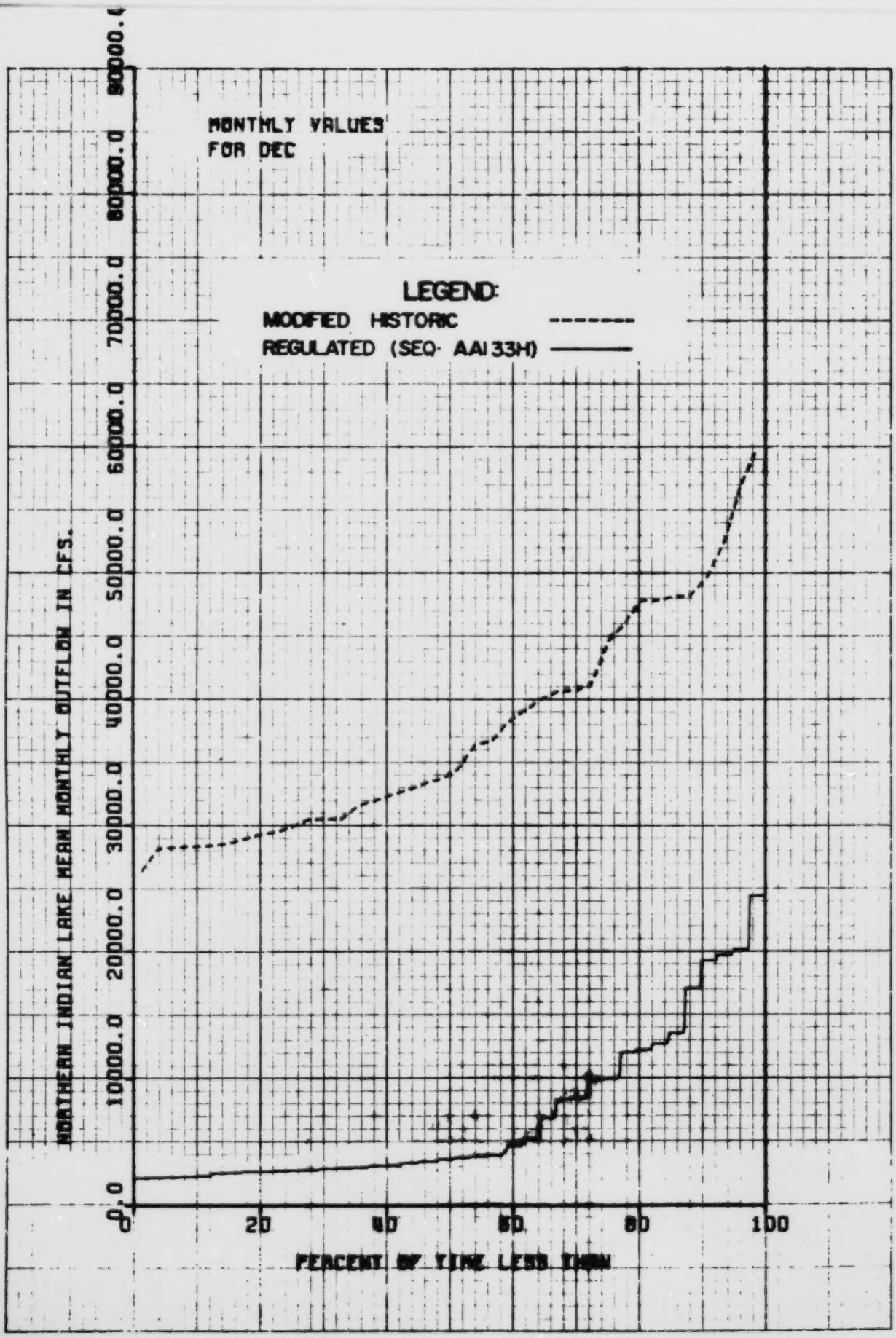

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
20
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIAN LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
NORTHERN INDIANA LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

FIDLER LAKE
LEVELS

FIDLER LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	0	87	0	84	8	79	34	66	66	18	45	3	55	0	71	18	50	26	16	57	8	82	5	87
1 - 2	0	13	0	16	0	13	0	0	16	0	26	0	26	0	11	0	0	21	3	22	5	5	0	8
2 - 4	0	0	0	0	0	0	0	0	0	0	24	0	18	0	0	0	3	0	3	0	0	0	0	0
4 - 6	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

MINIMUM	756.99	756.67	756.58	756.40	756.38	757.26	757.93	758.53	758.59	757.88	757.42	757.11	ANNUAL
AVERAGE	759.21	758.61	758.15	757.90	758.28	759.66	760.85	761.26	761.04	760.57	760.22	759.75	756.38
MAXIMUM	763.42	762.04	760.44	759.55	760.82	765.57	767.37	767.29	766.19	765.93	765.35	764.39	759.63
													767.37

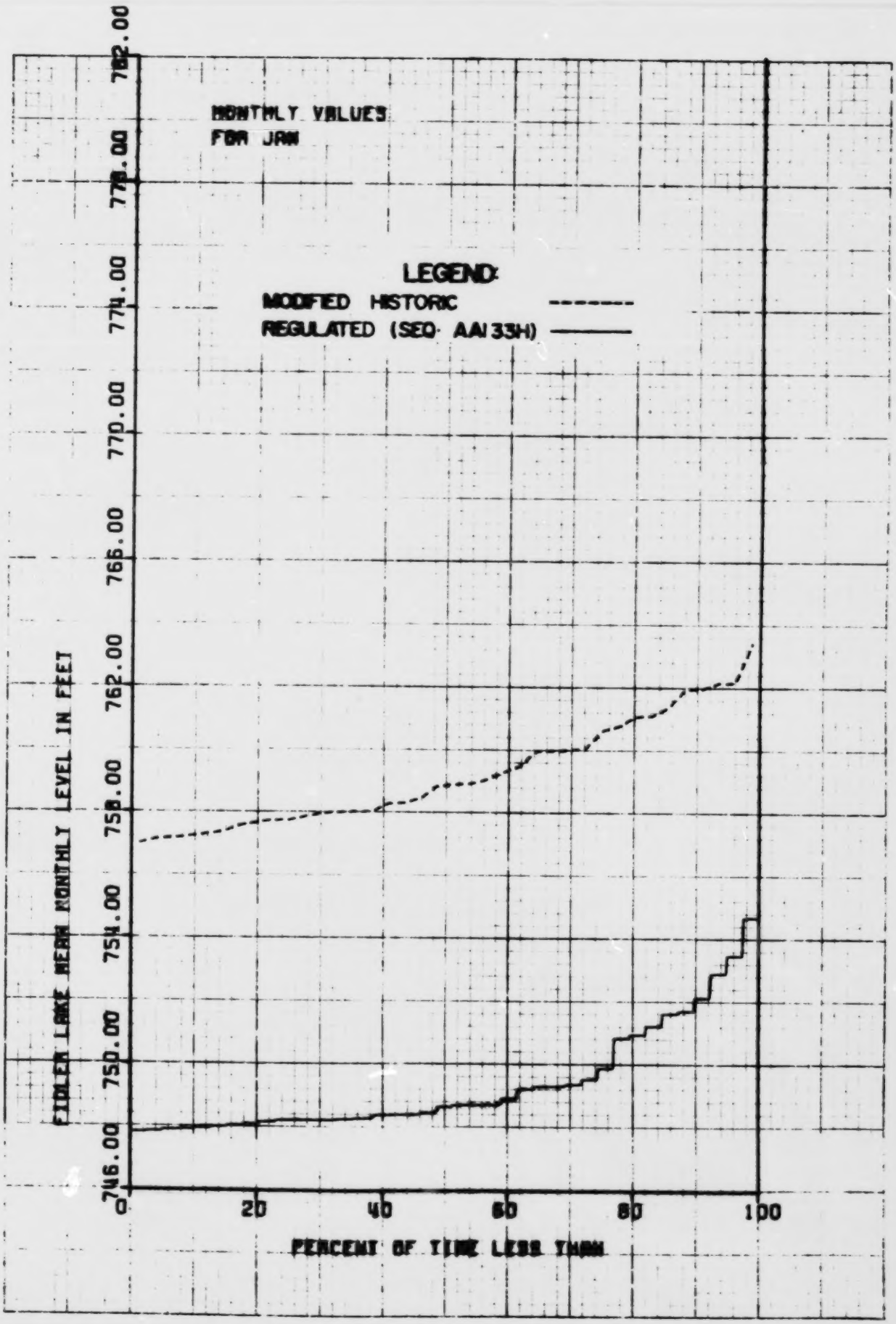
FIDLER LAKE - REGULATED CONDITIONS

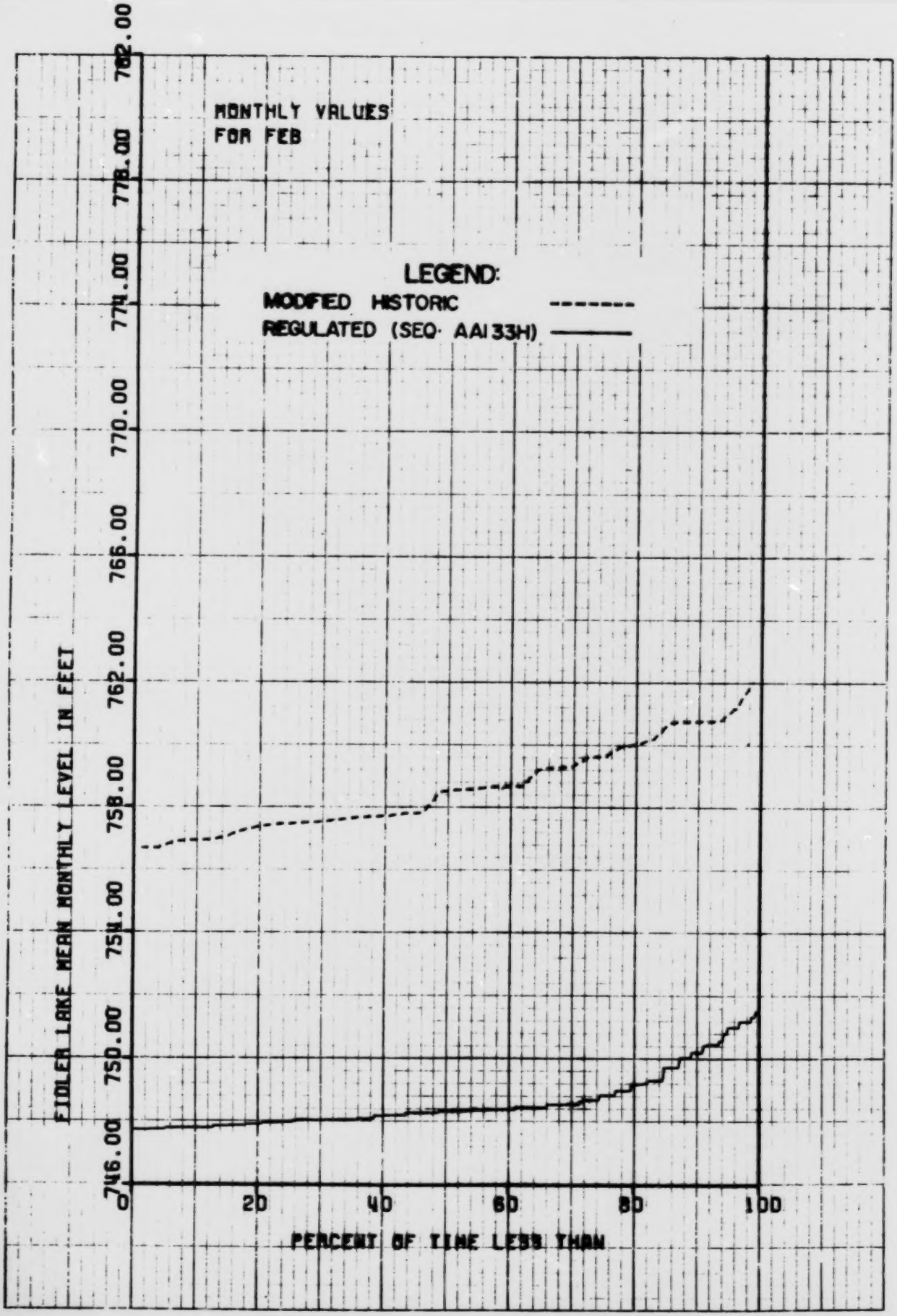
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

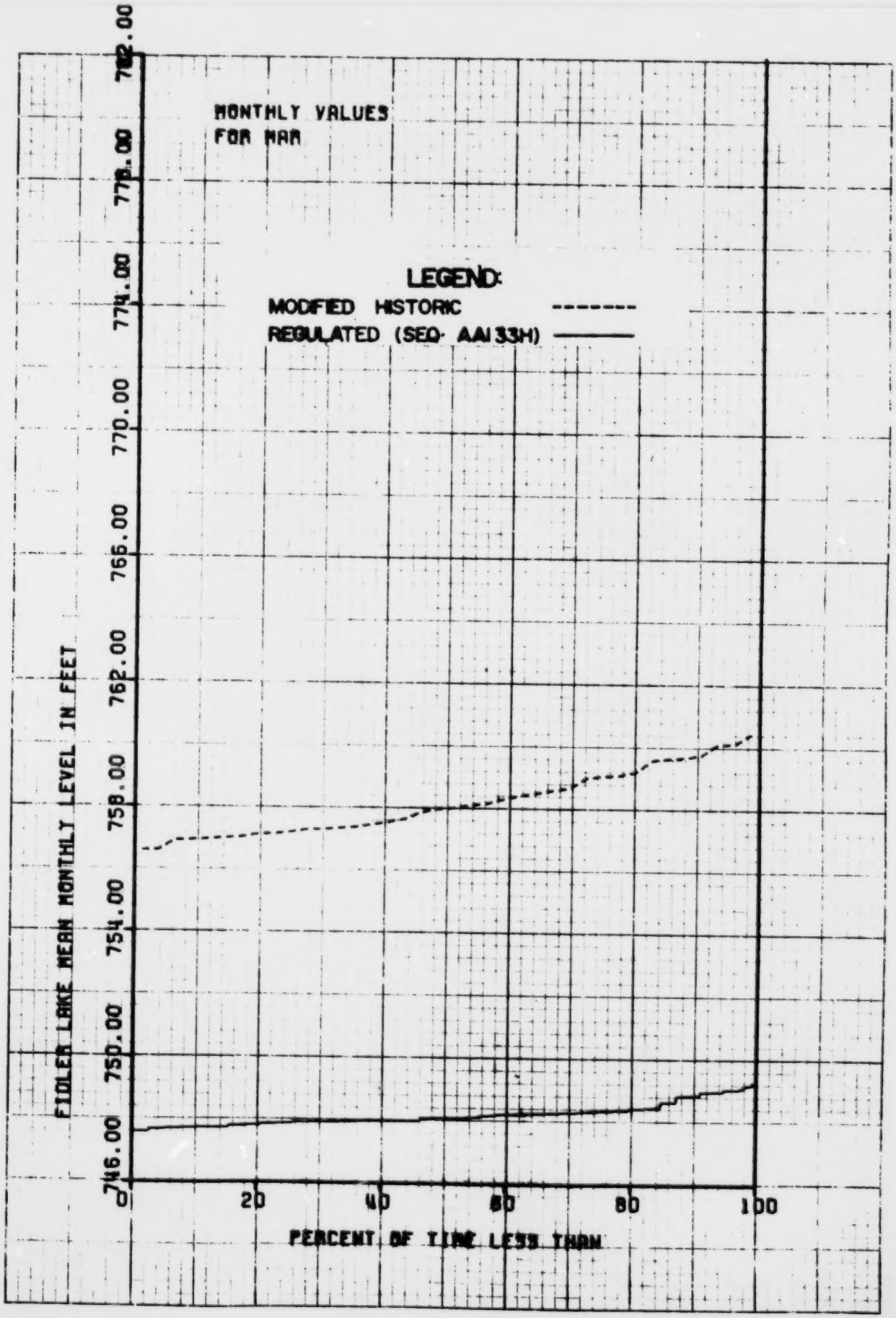
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	10	52	2	73	0	82	16	78	18	40	10	4	27	22	14	29	2	4	11	23	20	56	27	32
1 - 2	0	23	0	12	0	13	9	1	0	0	5	0	15	21	5	29	1	39	5	39	0	10	2	24
2 - 4	0	16	0	12	0	5	2	0	10	0	19	0	13	2	3	18	2	46	3	18	0	10	0	14
4 - 6	0	0	0	0	0	0	0	0	13	0	36	0	0	0	0	2	0	5	3	0	0	3	0	1
6 - 8	0	0	0	0	0	0	0	0	14	0	17	0	0	0	0	0	0	0	0	0	0	2	0	0
8 -	0	0	0	0	0	0	0	0	5	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0

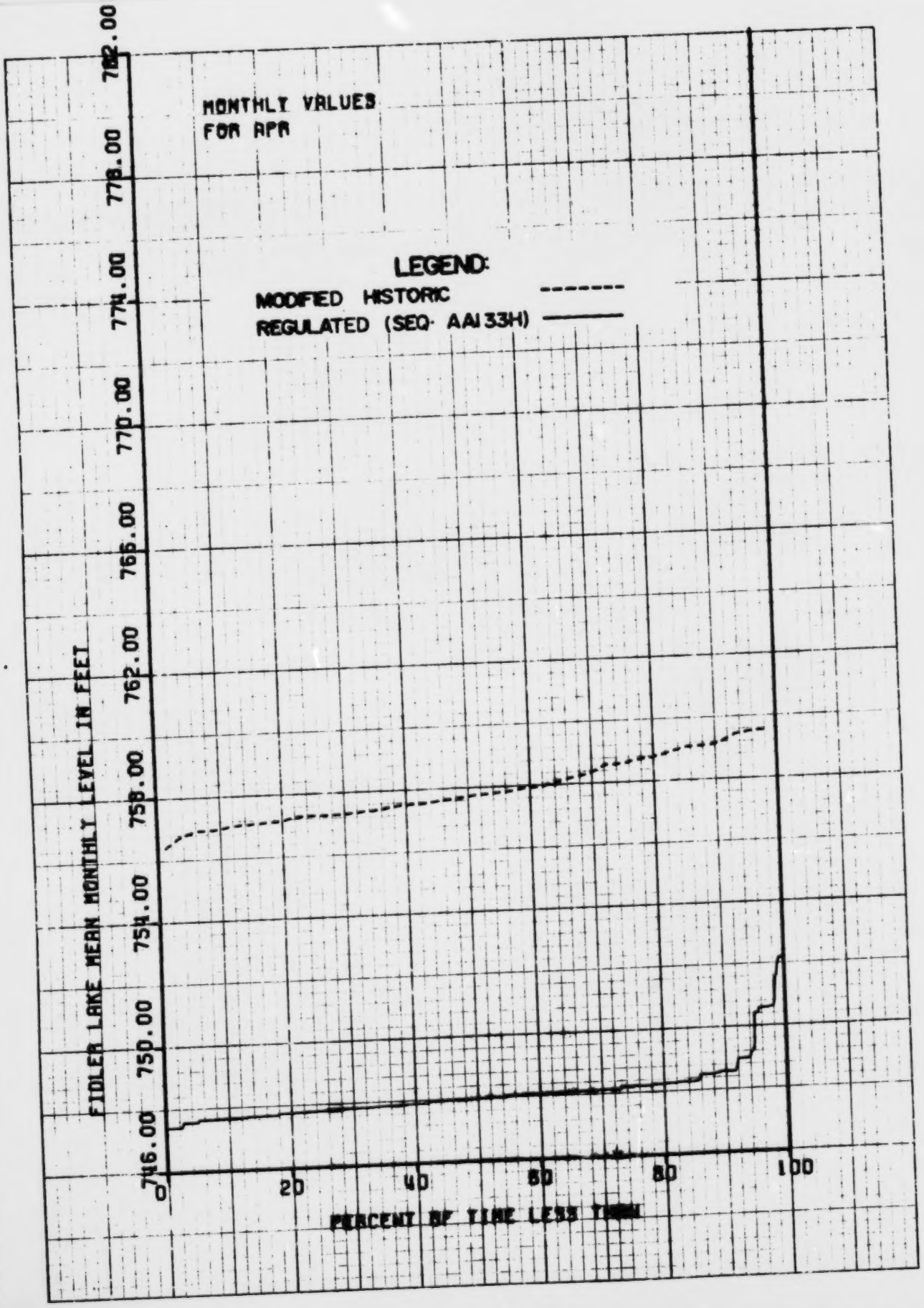
MEAN MONTHLY LEVELS IN FEET

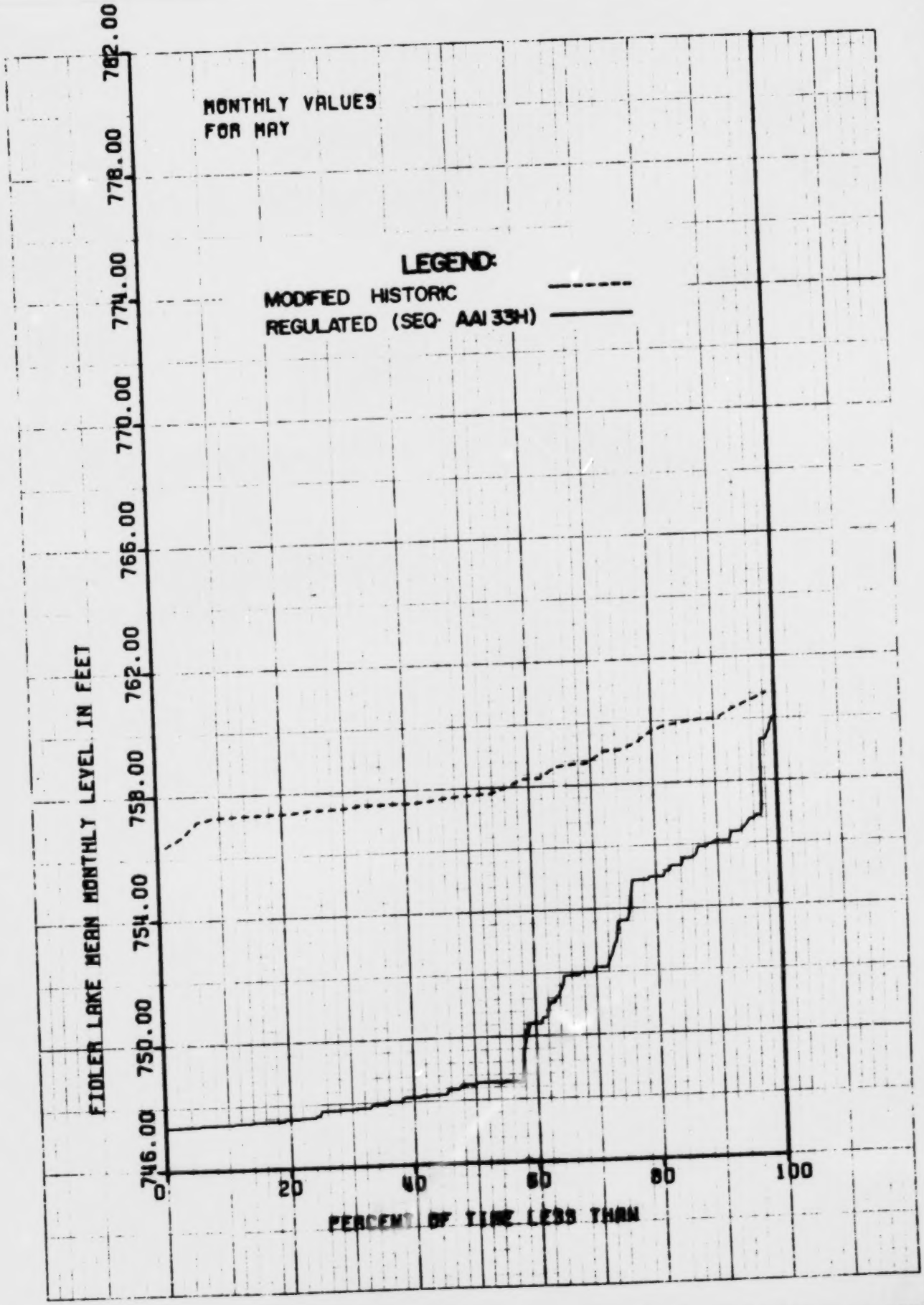
MINIMUM	747.79	747.70	747.57	747.39	747.34	747.20	747.66	748.10	747.60	747.65	747.63	747.78	ANNUAL
AVERAGE	749.32	748.58	748.14	748.13	750.54	755.07	755.31	754.37	752.26	751.85	751.03	750.22	747.20
MAXIMUM	754.65	751.50	749.24	752.18	759.98	766.36	763.81	761.16	759.42	765.54	759.77	756.77	751.24
													766.38

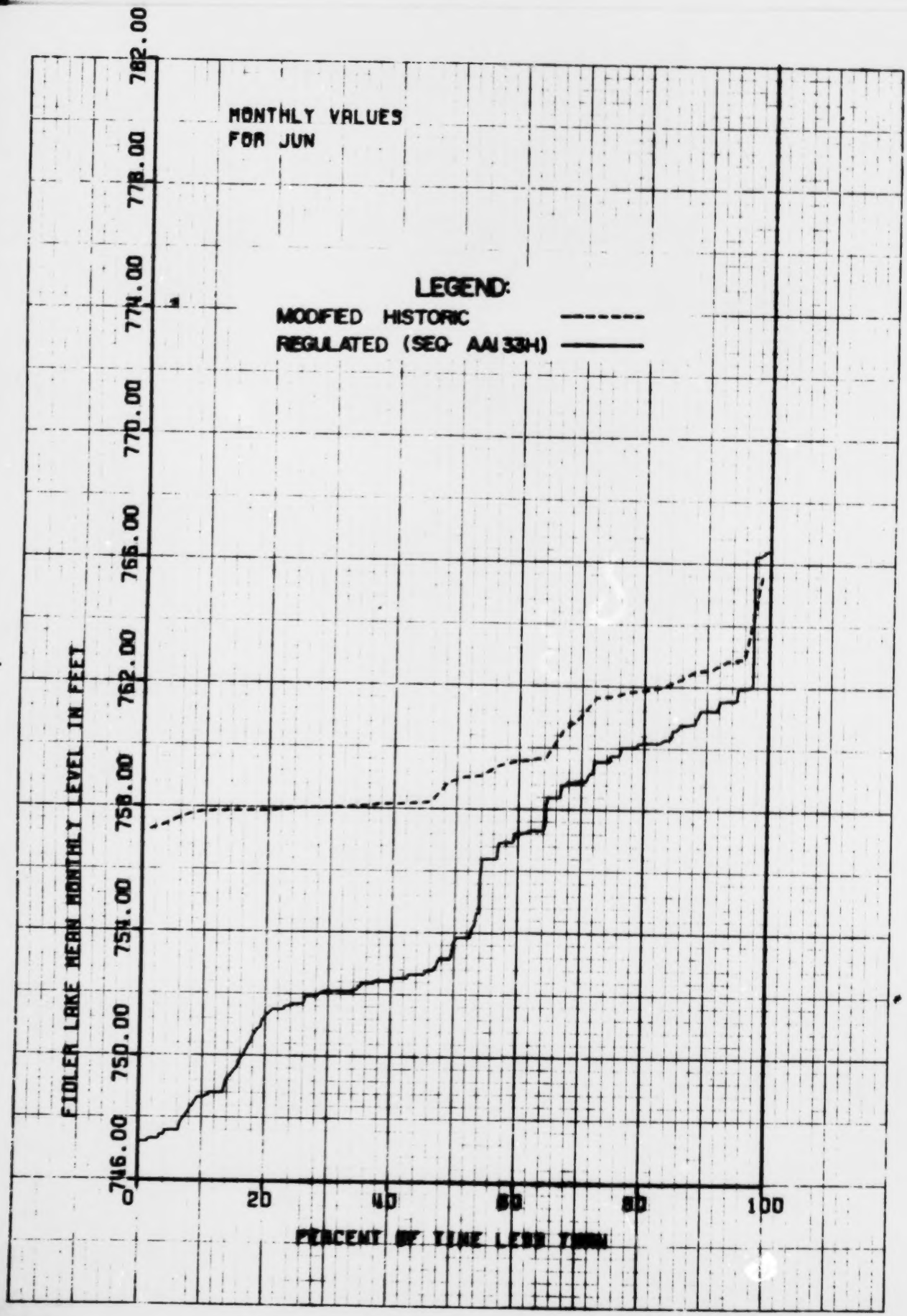

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

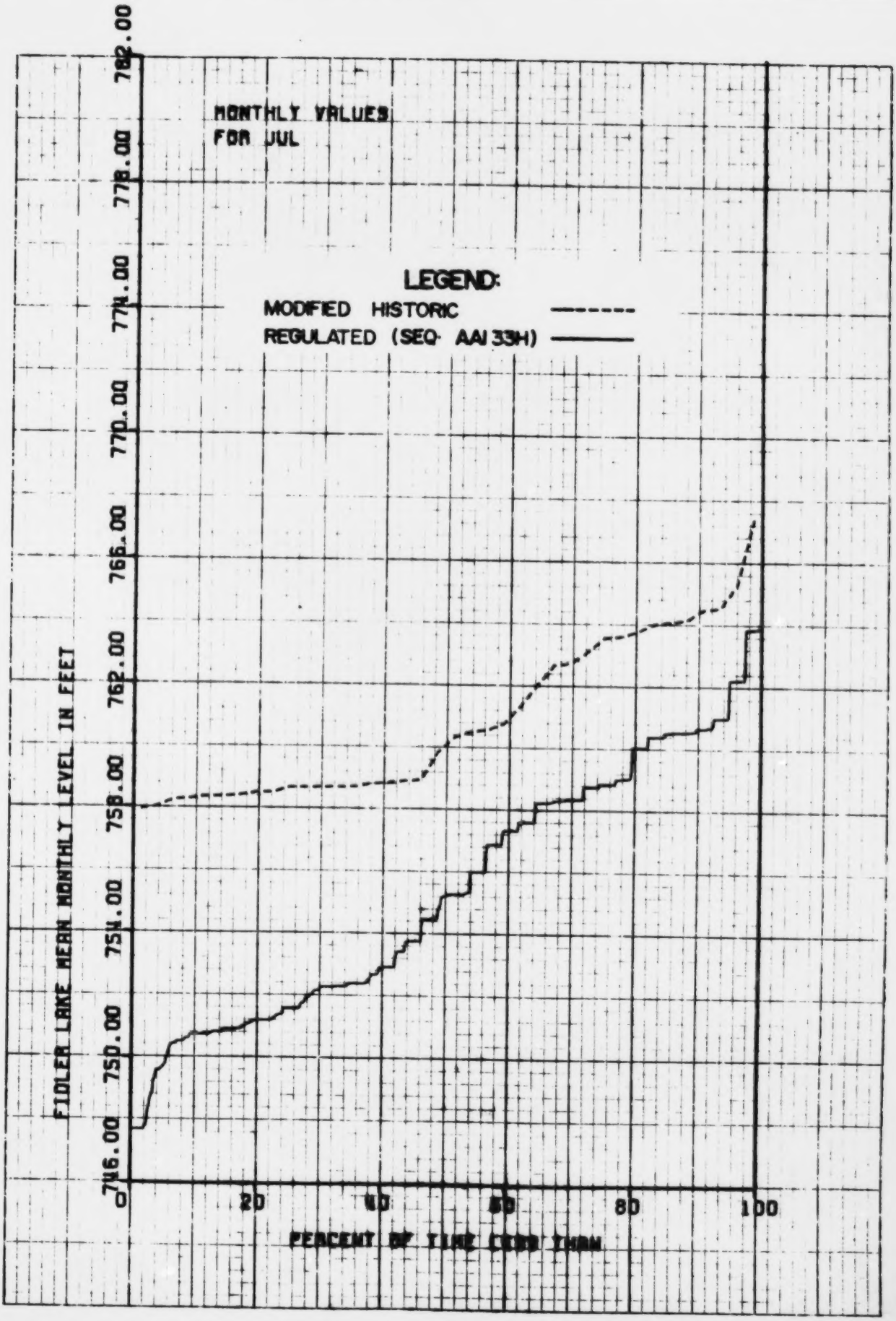

MONTHLY VALUES
FOR FEB
LEGEND:
MODFIED HISTORIC
REGULATED (SEQ. AAI33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

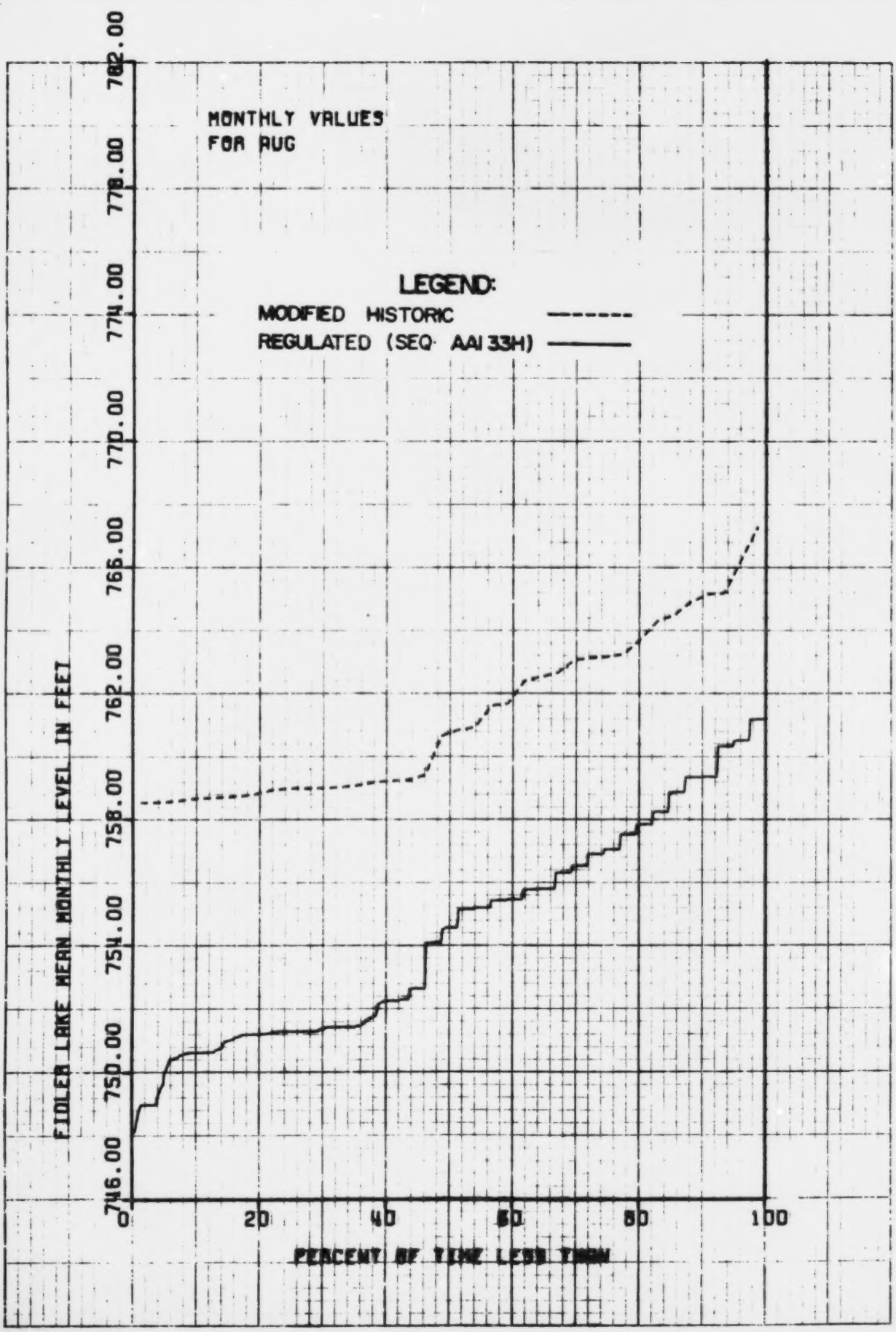

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

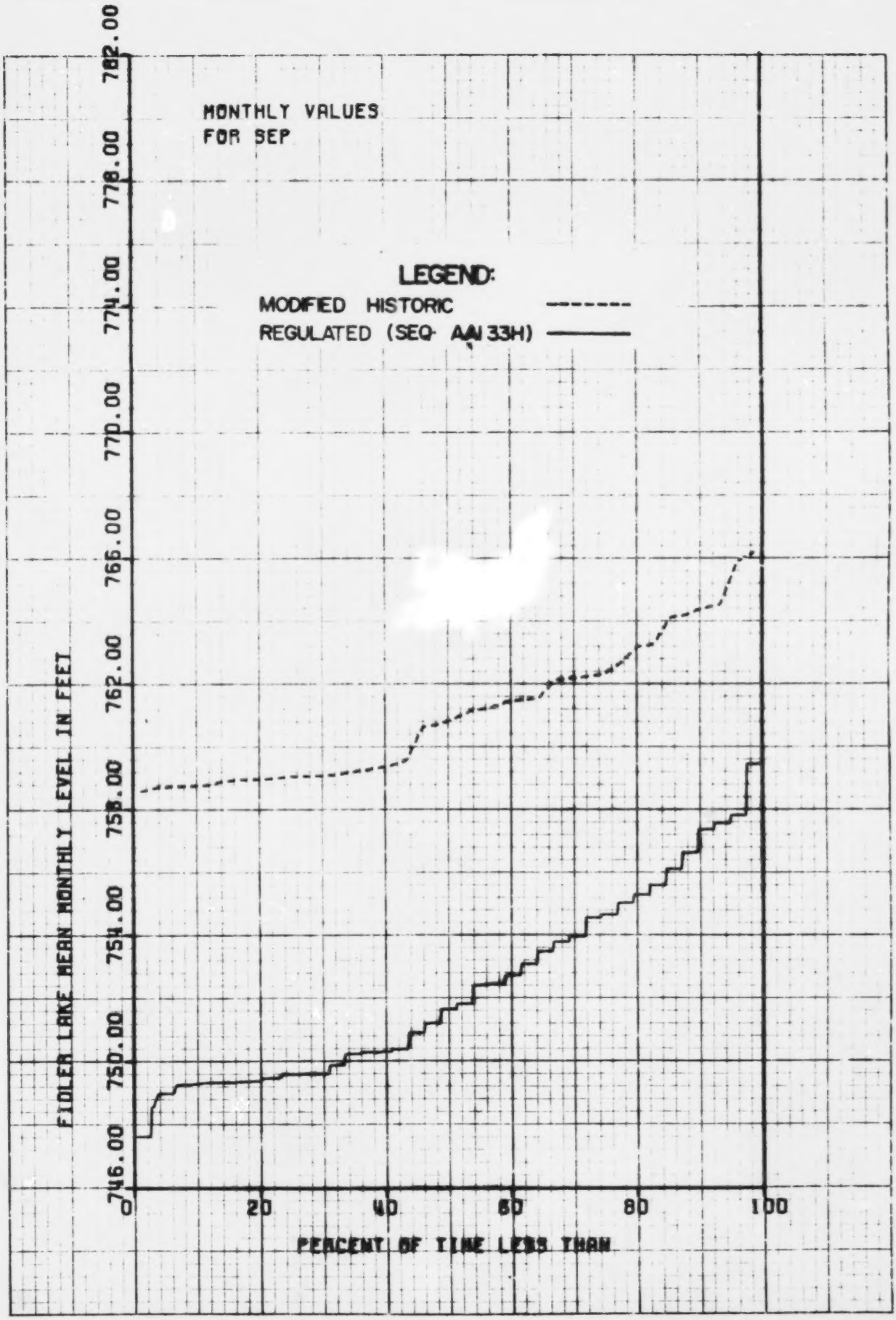

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
742.00
746.00
750.00
754.00
758.00
762.00
766.00
770.00
774.00
778.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

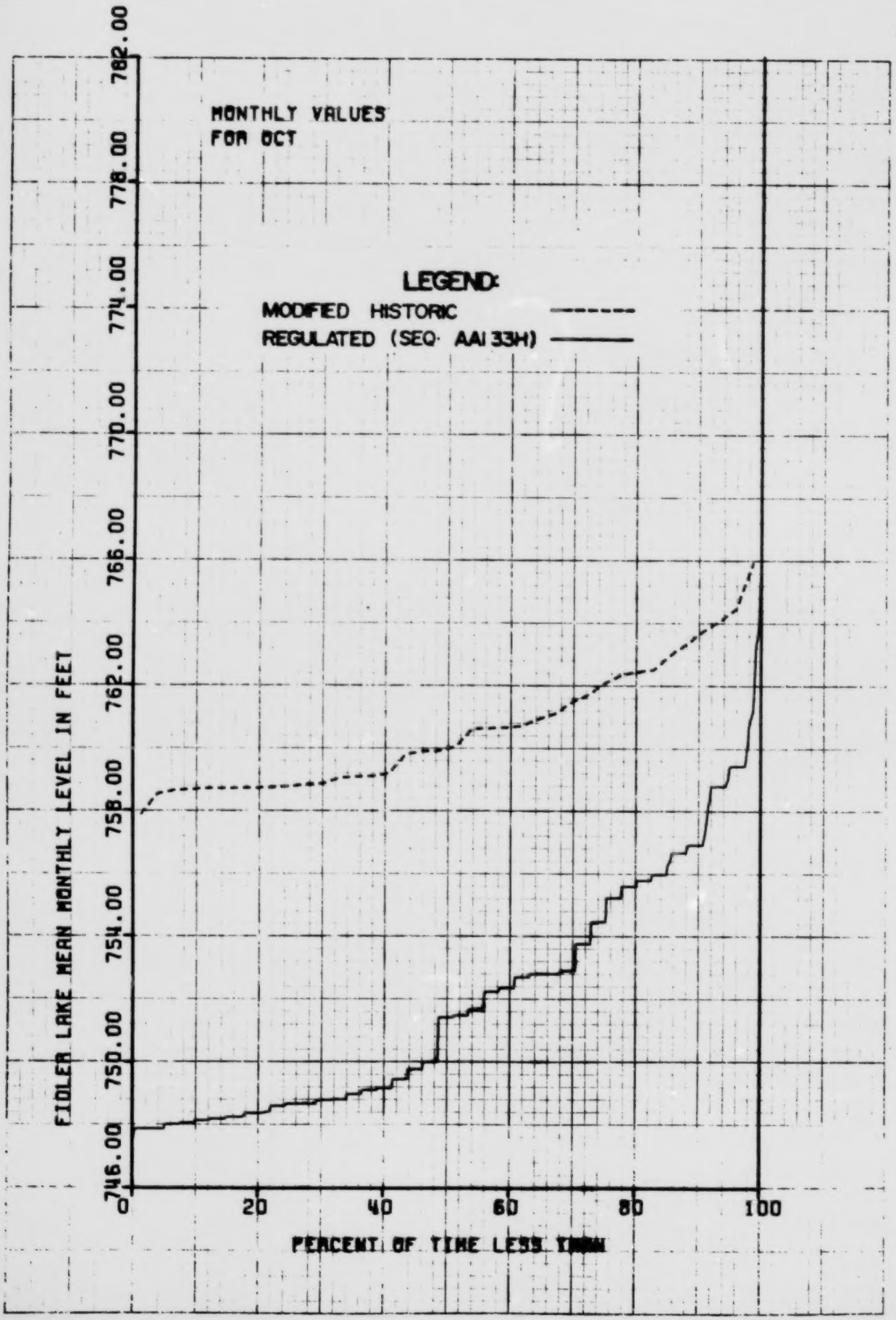

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

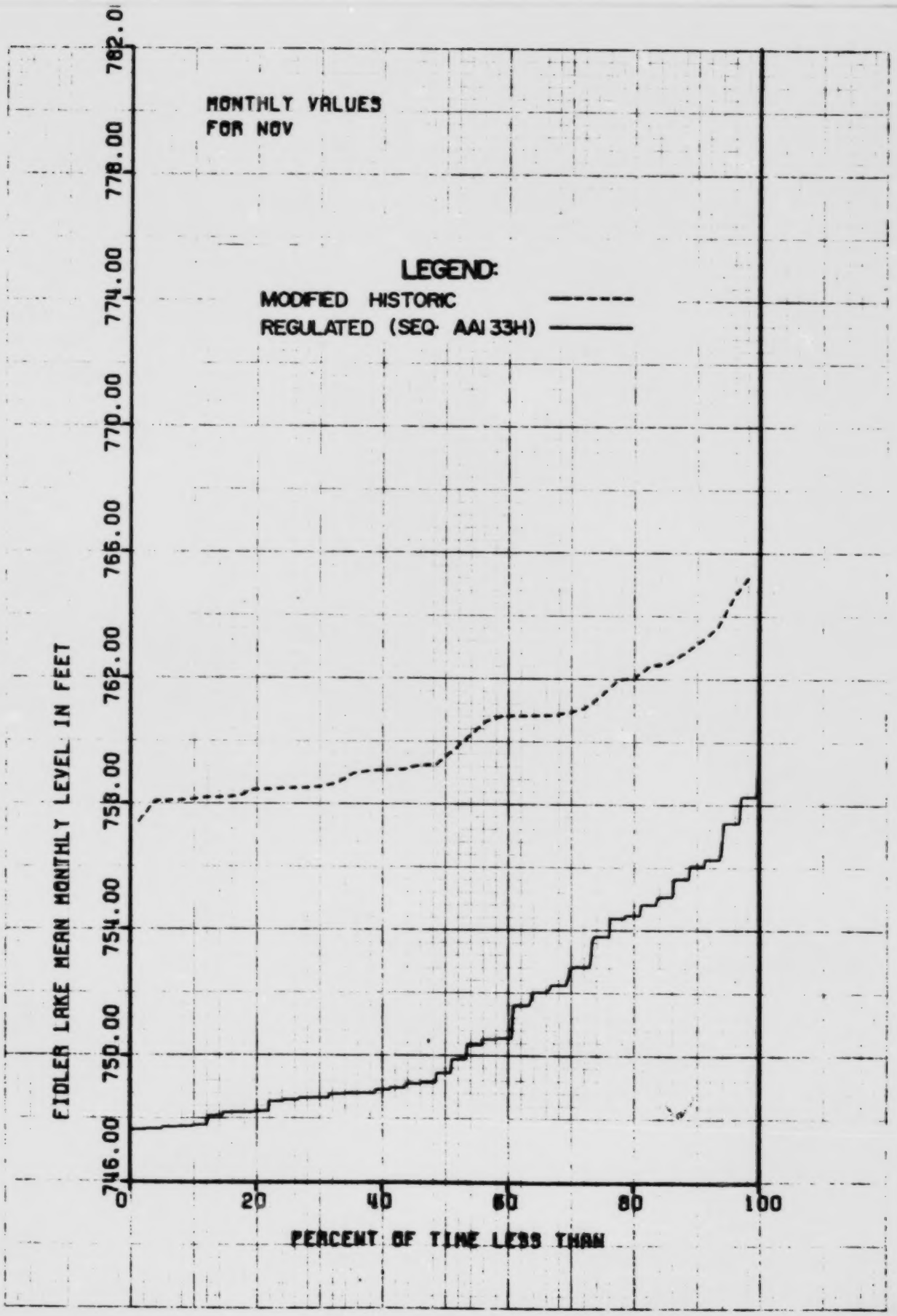

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AA133H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

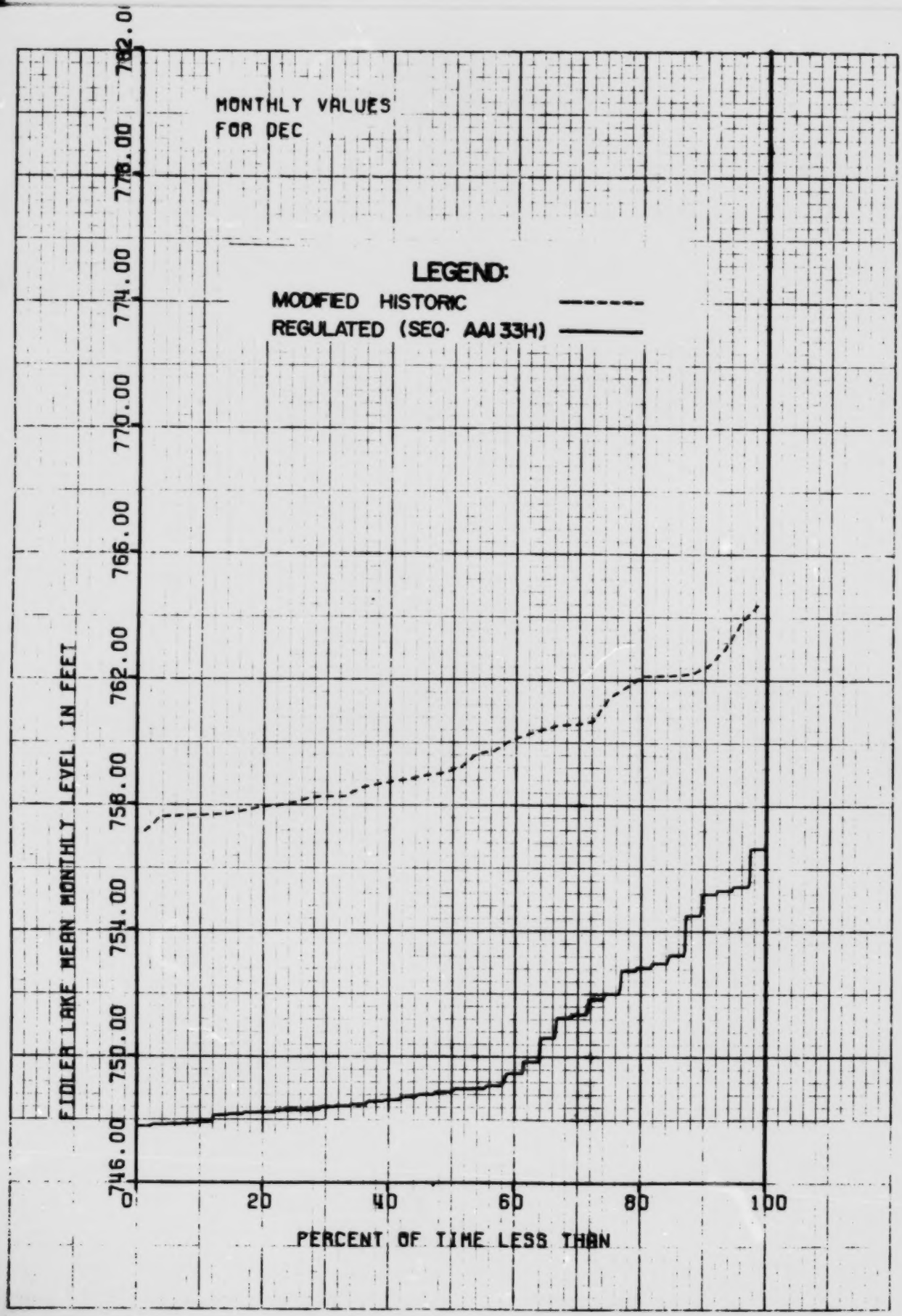

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME EQUAL THAN


MONTHLY VALUES
FOR RUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAN 33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.00
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
746.00
750.00
754.00
758.00
762.00
766.00
770.00
774.00
778.00
782.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.0
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
FIDLER LAKE MEAN MONTHLY LEVEL IN FEET
782.0
778.00
774.00
770.00
766.00
762.00
758.00
754.00
750.00
746.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

FIDLER LAKES
OUTFLOWS

FIDLER LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	0	87	0	87	8	84	34	66	74	18	50	3	61	0	66	18	47	29	19	57	8	82	5	87
5 - 10	0	13	0	13	0	8	0	0	8	0	21	0	16	0	13	3	3	21	0	22	5	5	0	8
10 - 20	0	0	0	0	0	0	0	0	0	0	24	0	24	0	0	0	0	0	3	0	0	0	0	0
20 - 30	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

													ANNUAL
MINIMUM	26,070	24,880	24,570	23,890	23,820	27,050	29,550	31,790	32,010	29,360	27,680	26,490	23,820
AVERAGE	35,222	32,628	30,631	29,568	31,193	37,301	42,942	44,855	43,645	41,342	39,732	37,624	37,223
MAXIMUM	55,090	47,810	40,410	36,380	42,180	66,790	77,510	76,980	70,370	68,850	65,360	60,180	77,510

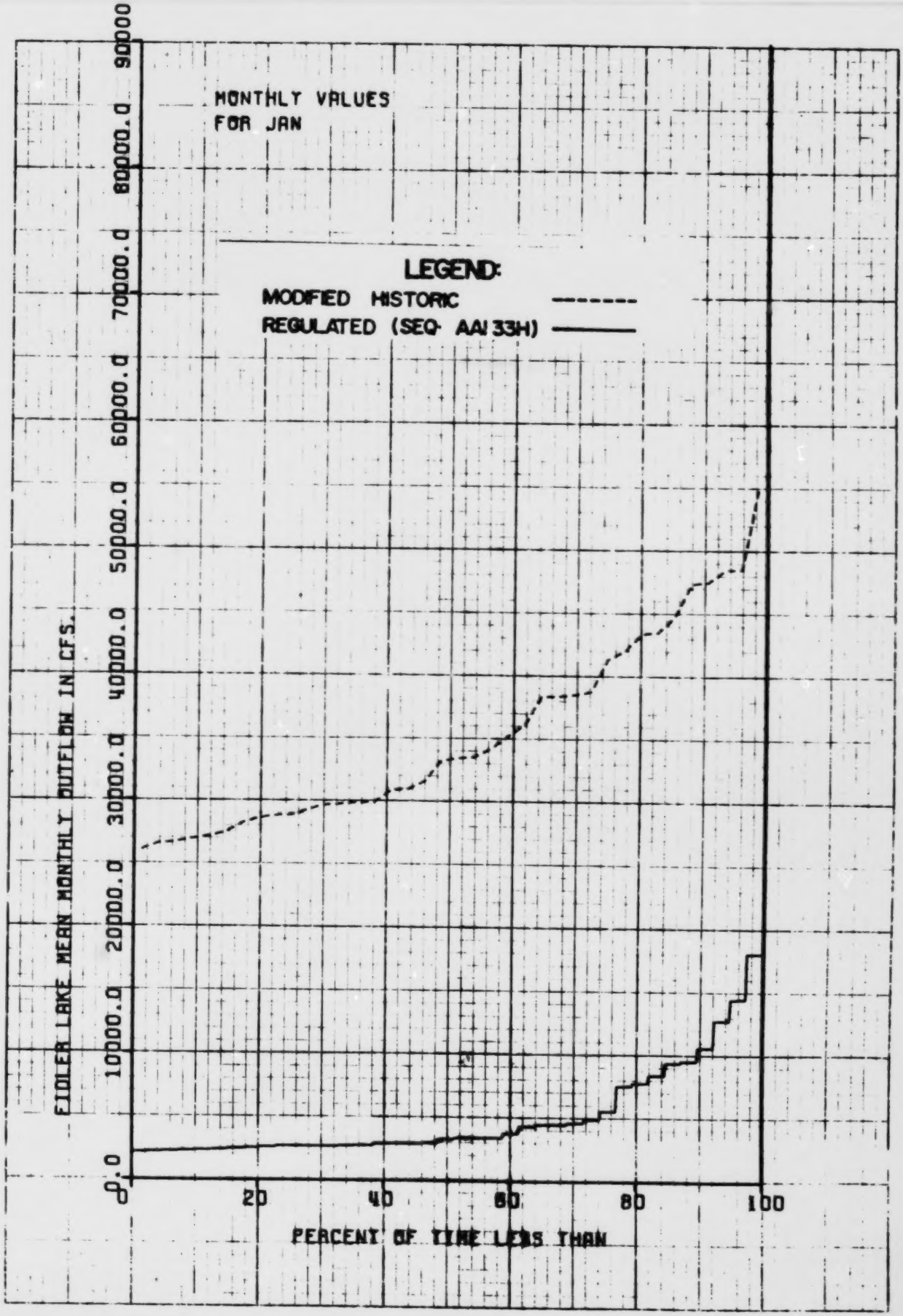
FIDLER LAKE - REGULATED CONDITIONS

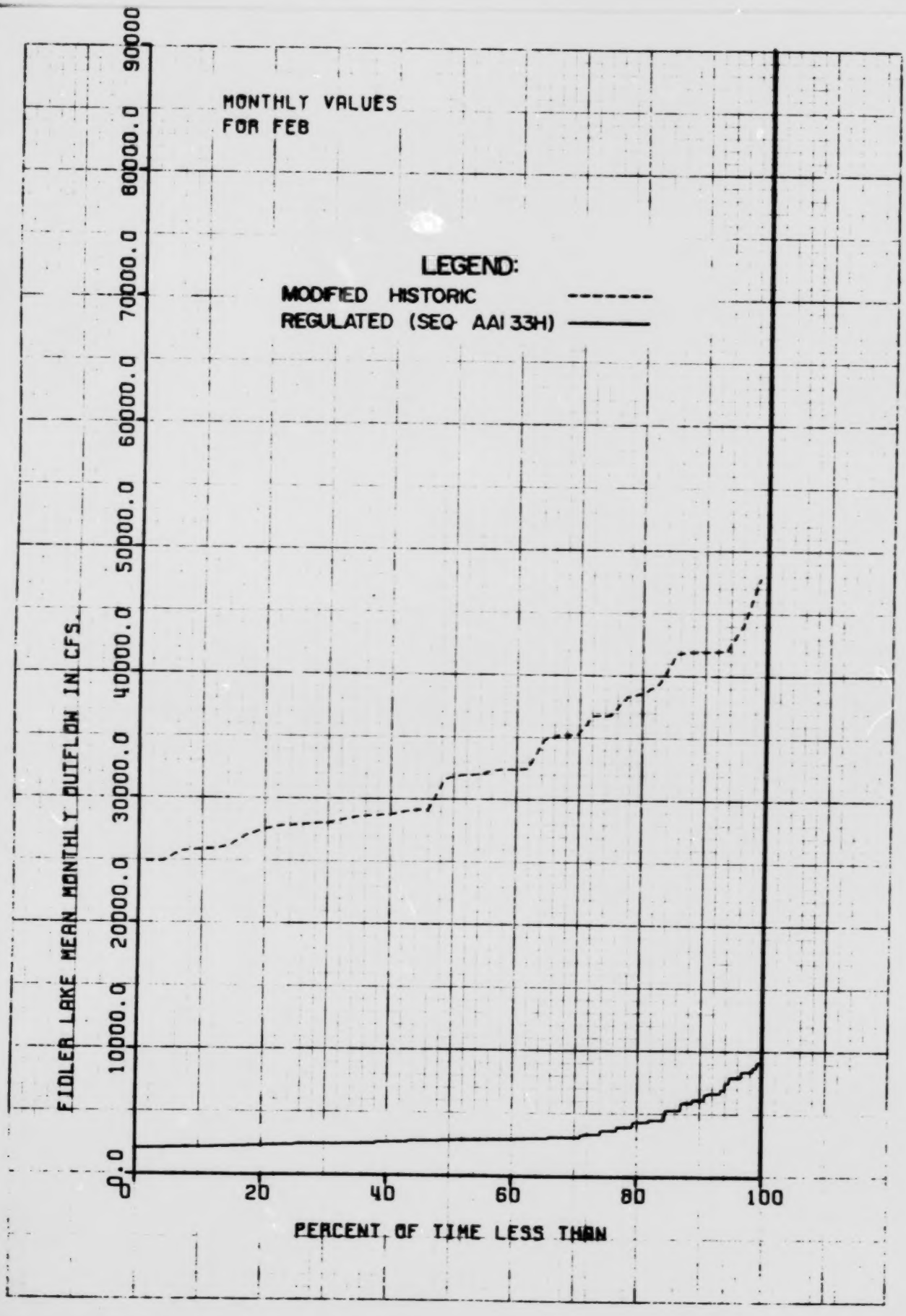
AVERAGE FLOW FLUCTUATIONS IN PERCENT

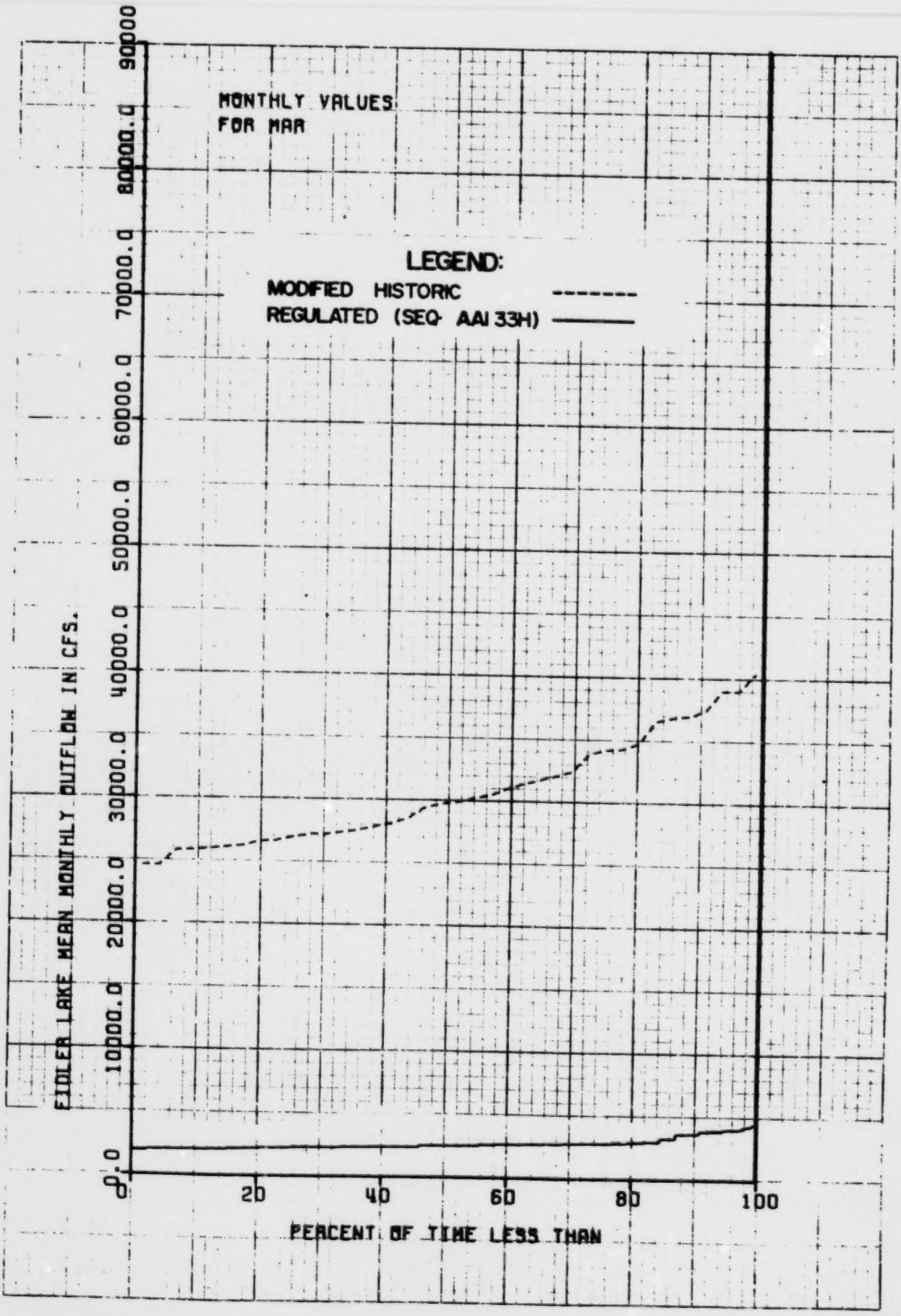
RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	10	72	2	87	0	99	20	79	24	37	15	4	45	30	20	47	4	40	16	64	18	67	29	56
5 - 10	0	18	0	11	0	1	2	0	12	0	33	0	9	14	2	13	2	30	0	13	0	10	0	10
10 - 20	0	0	0	0	0	0	0	0	20	0	18	0	0	2	0	18	0	21	5	3	0	2	0	4
20 - 30	0	0	0	0	0	0	0	0	4	0	21	0	0	0	0	0	0	2	0	0	0	3	0	0
30 - 40	0	0	0	0	0	0	0	0	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

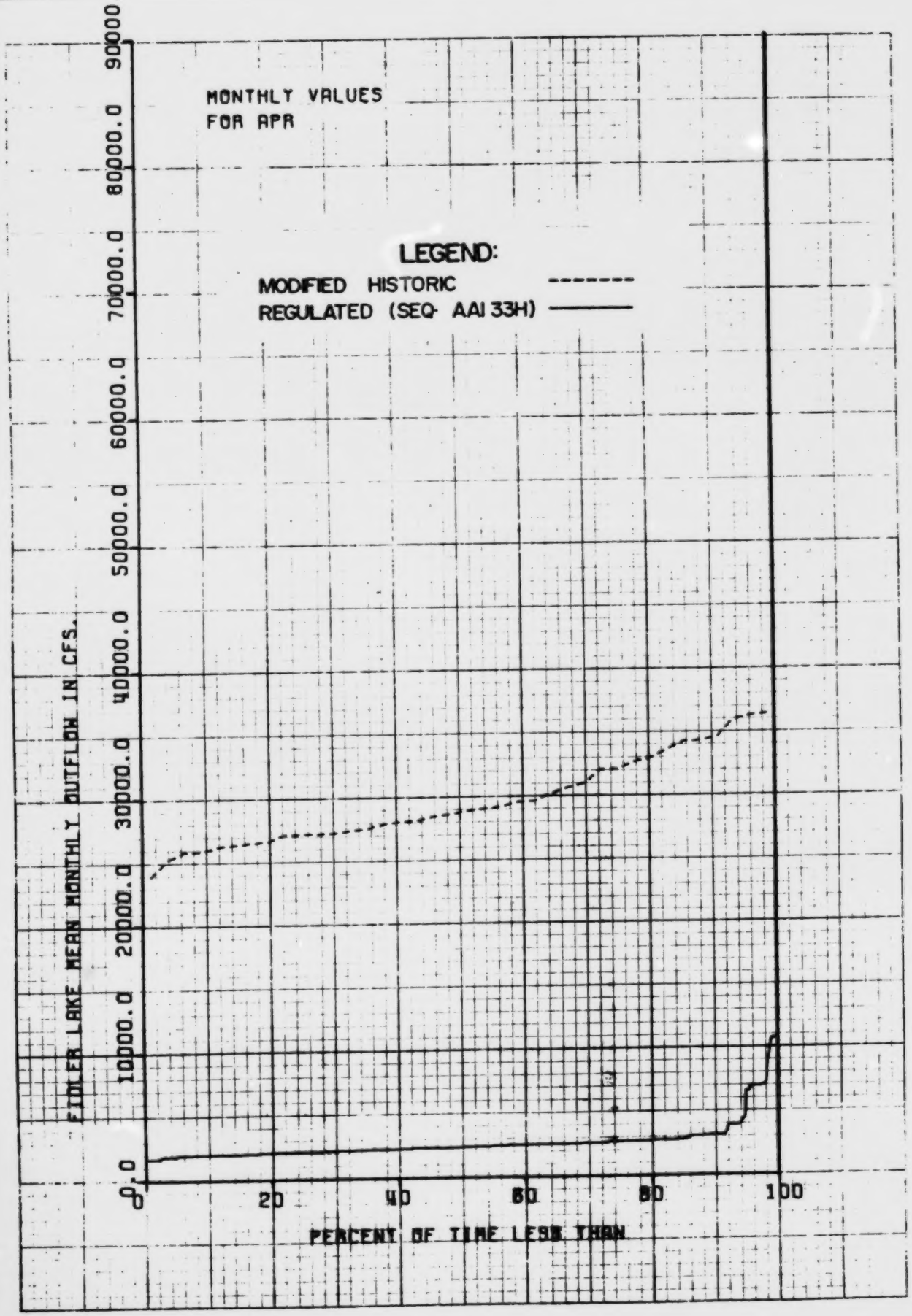
MEAN MONTHLY FLOWS IN CFS.

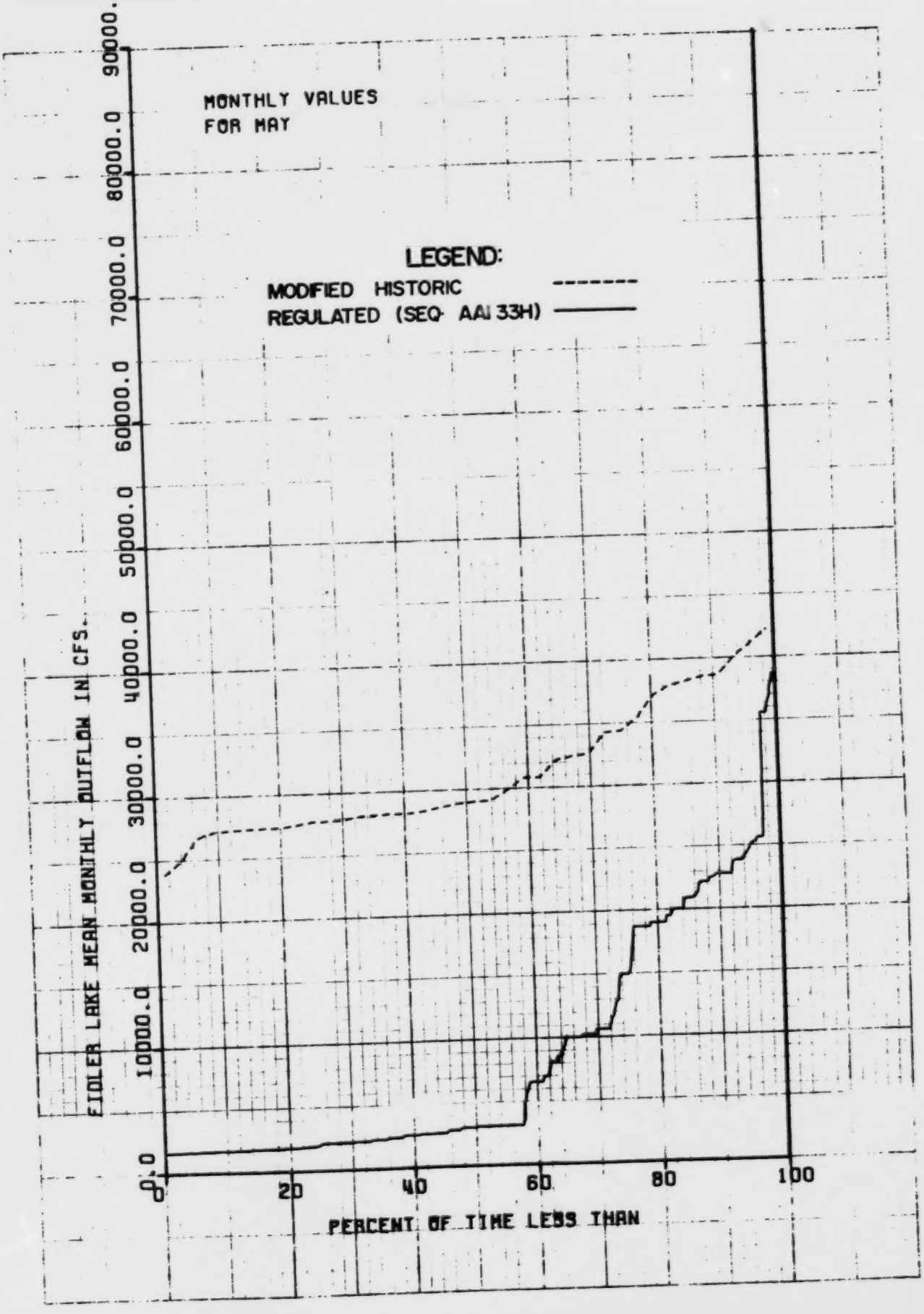
													ANNUAL
MINIMUM	2,110	2,000	1,840	1,620	1,550	1,420	1,950	2,500	1,880	1,930	1,910	2,110	1,420
AVERAGE	4,902	3,355	2,591	2,650	8,613	22,190	22,134	18,437	12,175	11,762	9,292	7,104	10,434
MAXIMUM	18,000	9,100	4,360	10,700	38,600	71,440	57,110	43,650	35,760	66,470	37,370	25,210	71,440

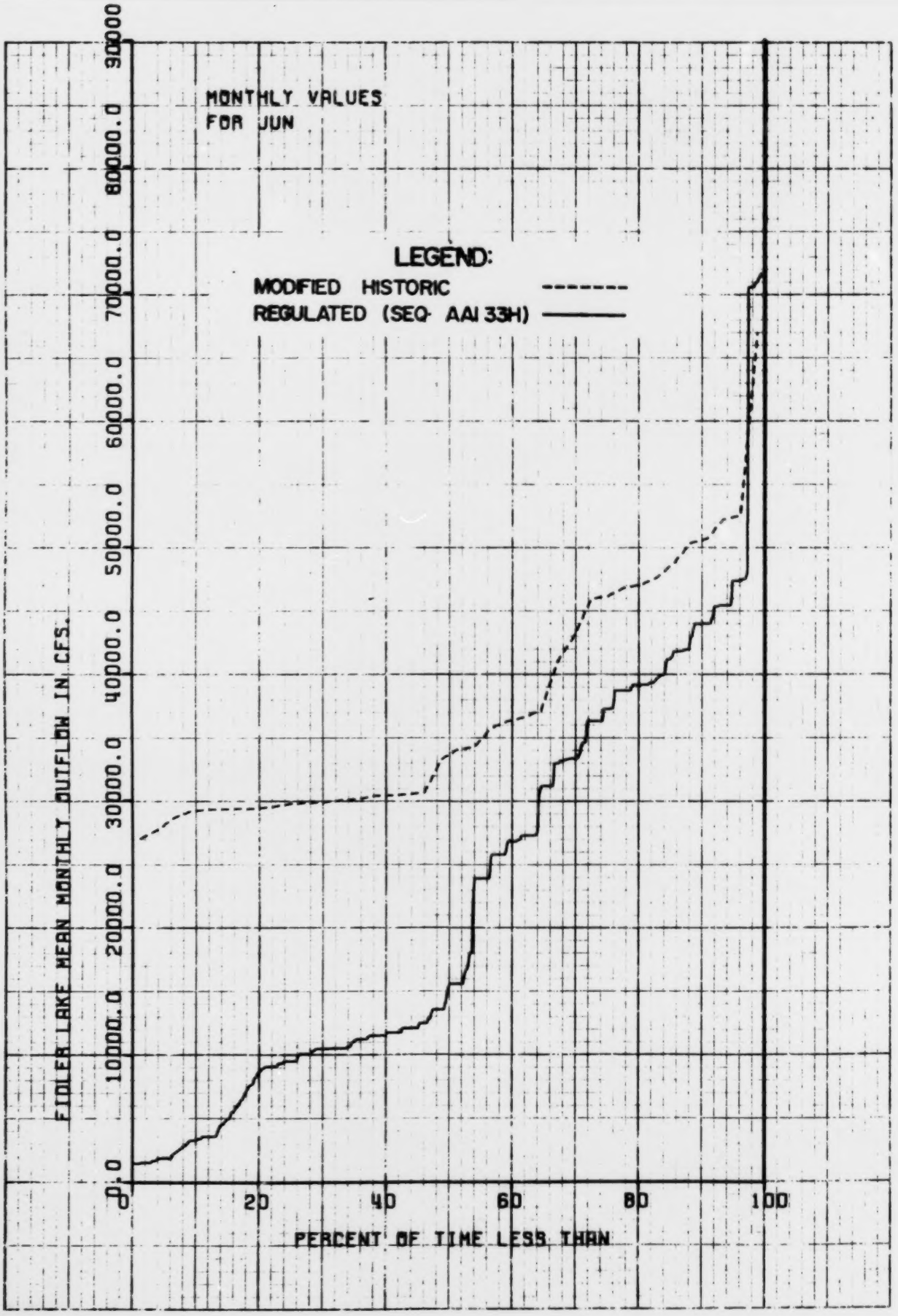

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
20
40
60
80
100
PERCENT OF TIME LESS THAN

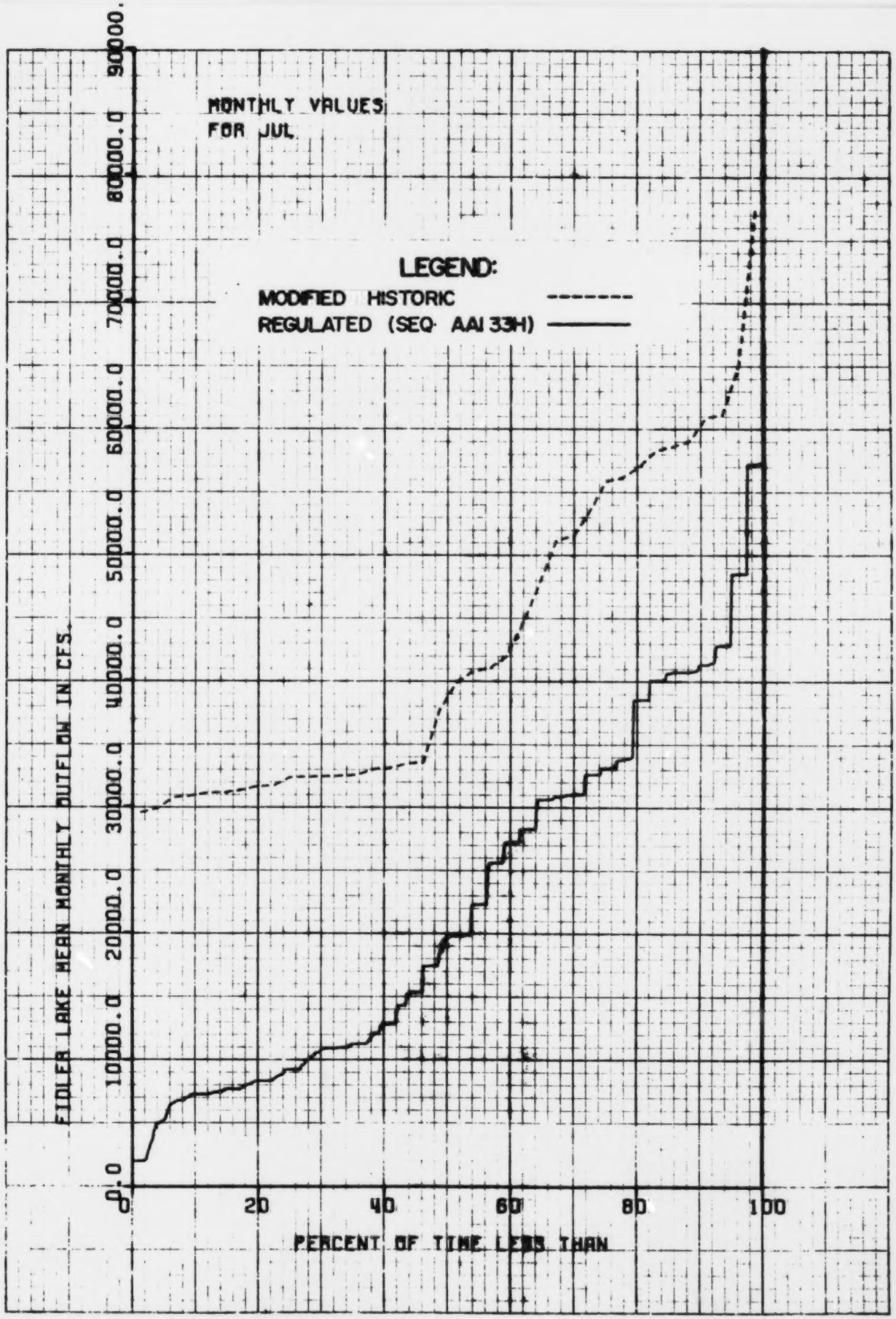

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

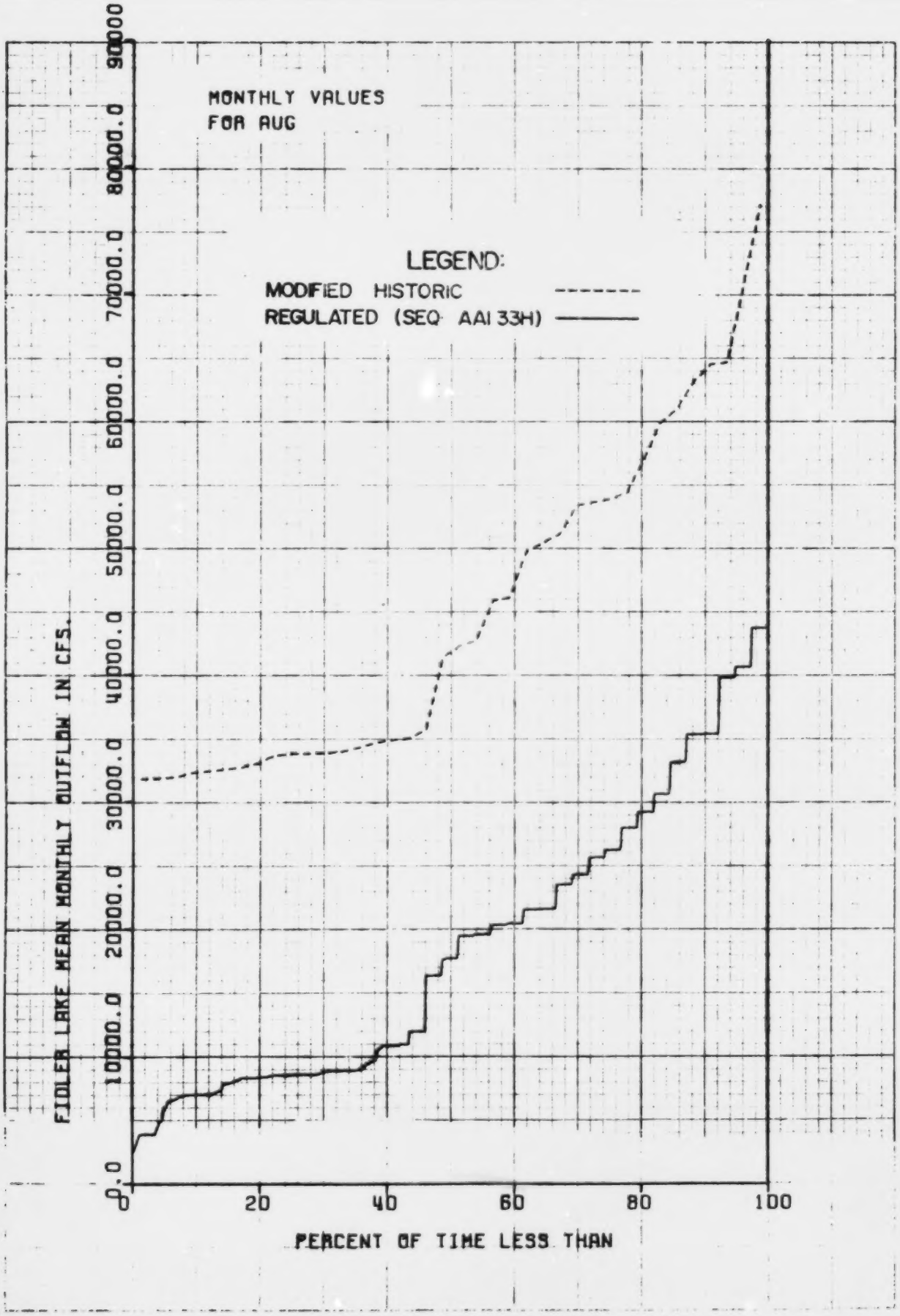

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
90000
80000.0
70000.0
60000.0
50000.0
40000.0
30000.0
20000.0
10000.0
0.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

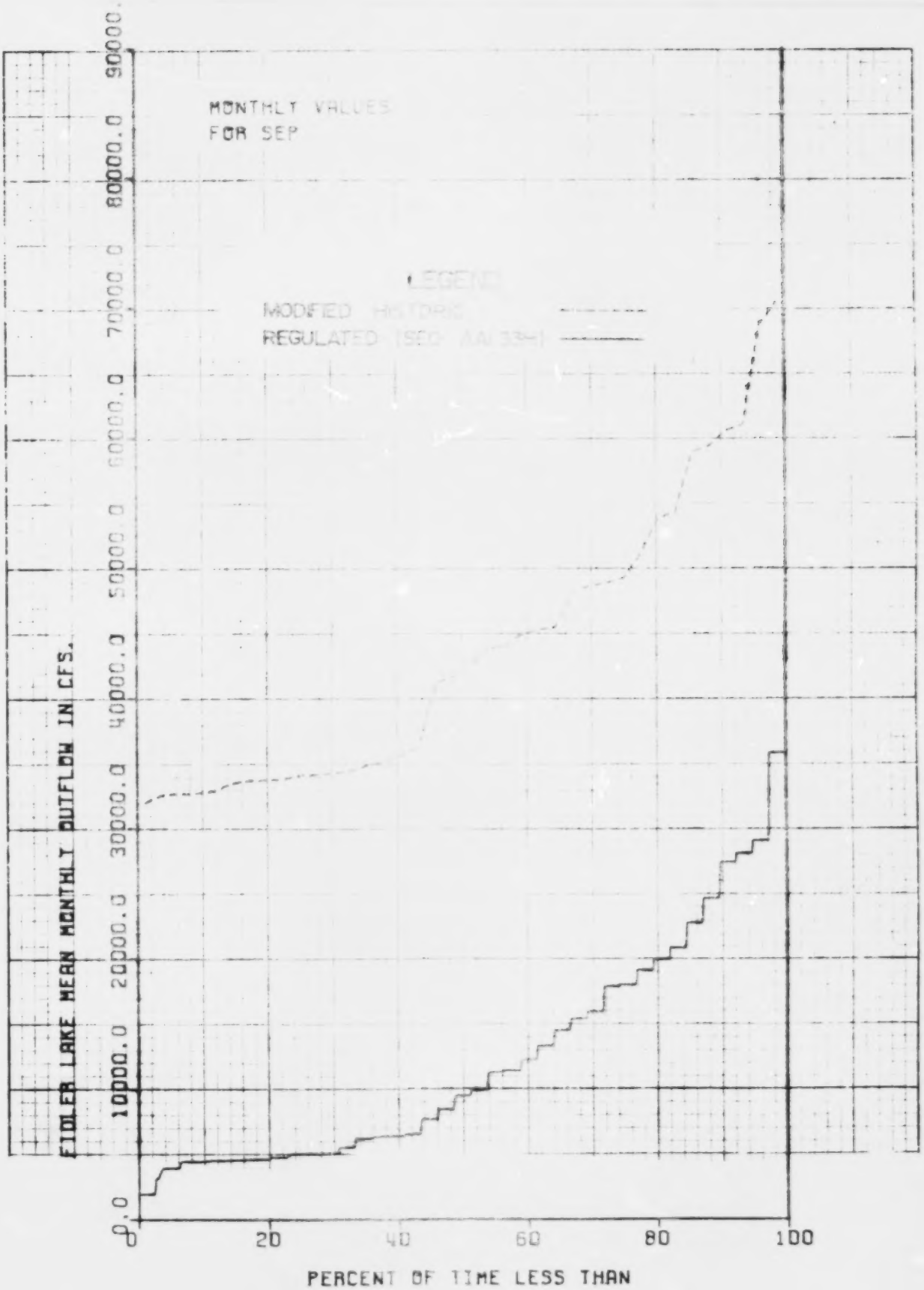

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

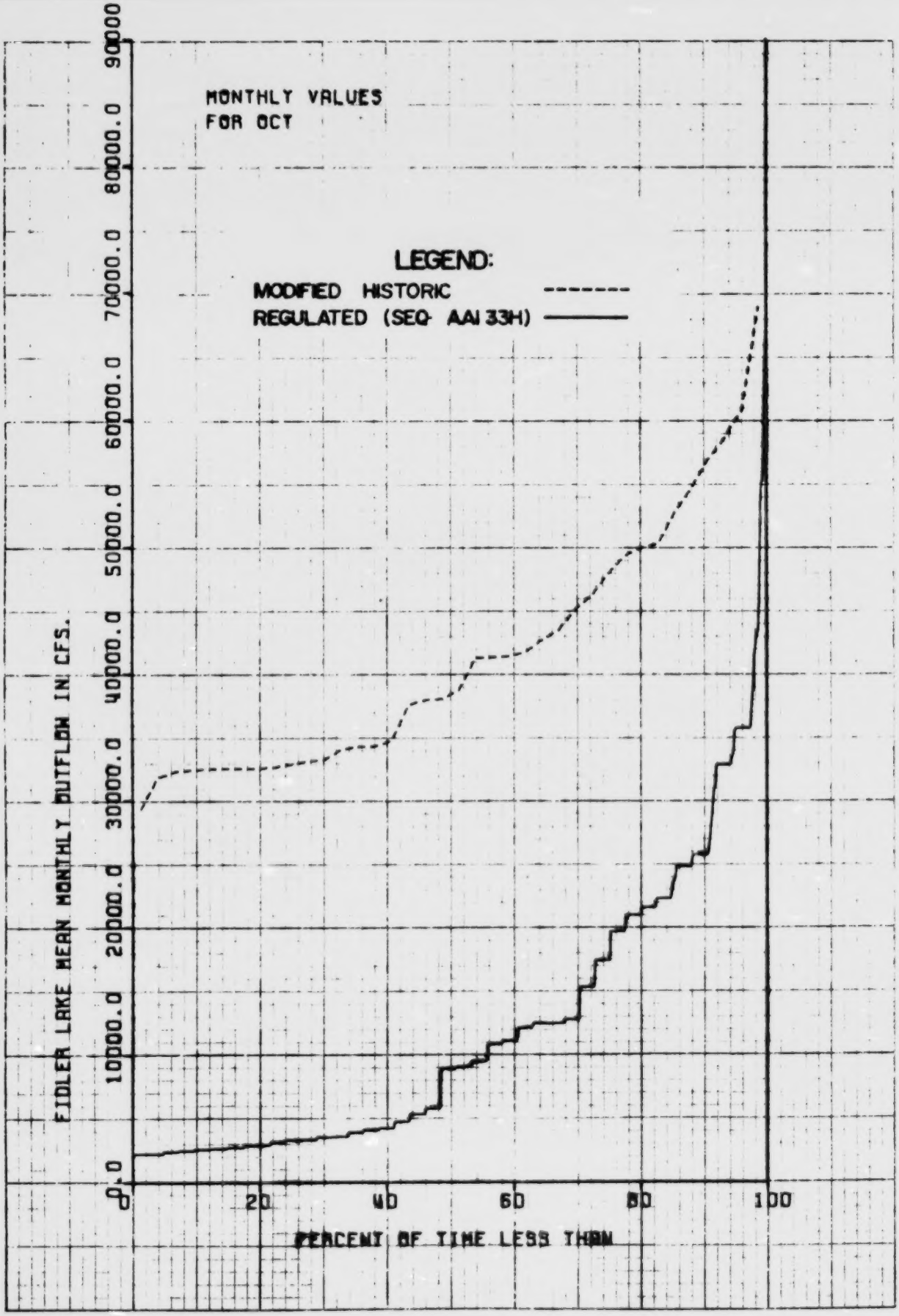

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

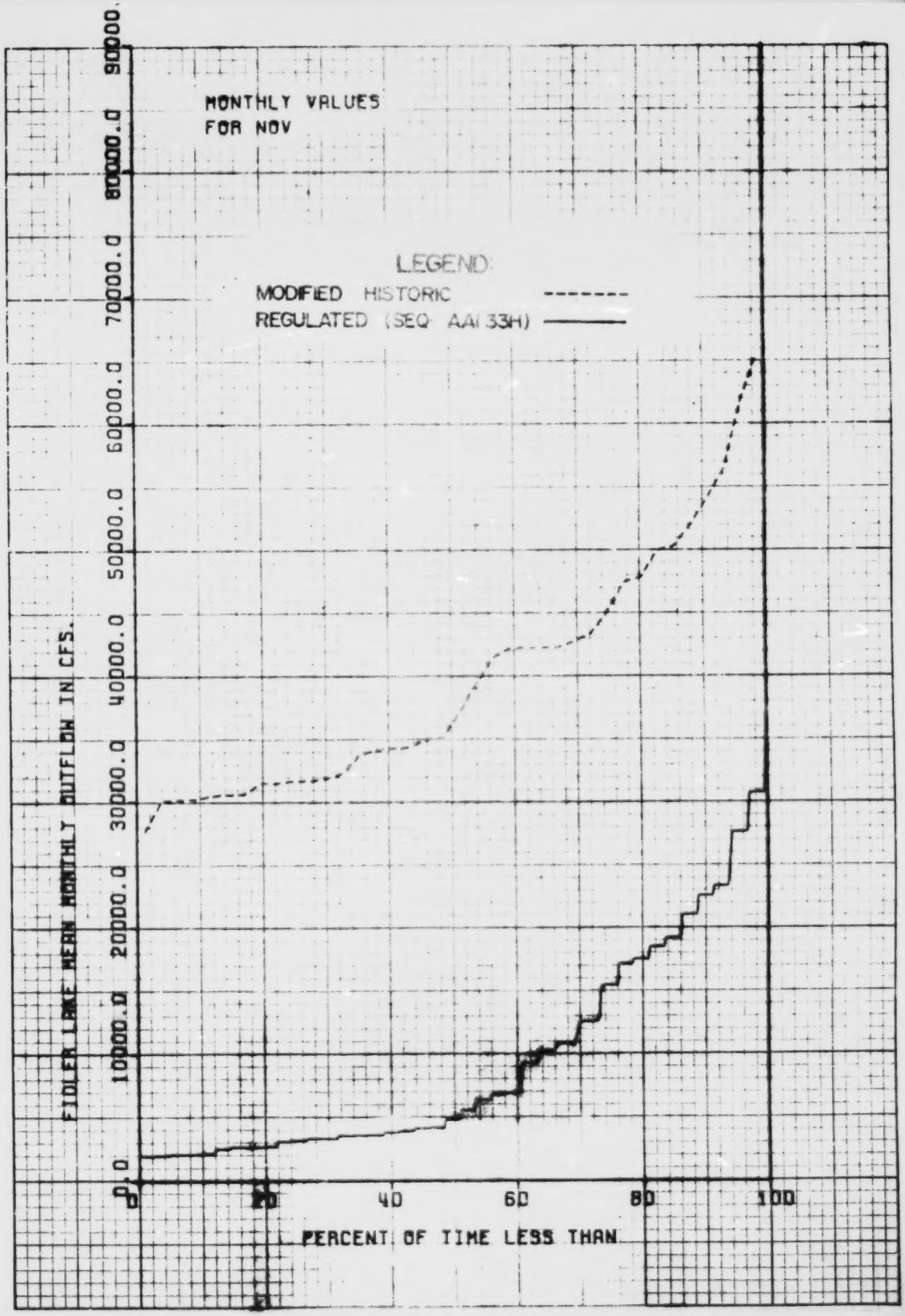

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

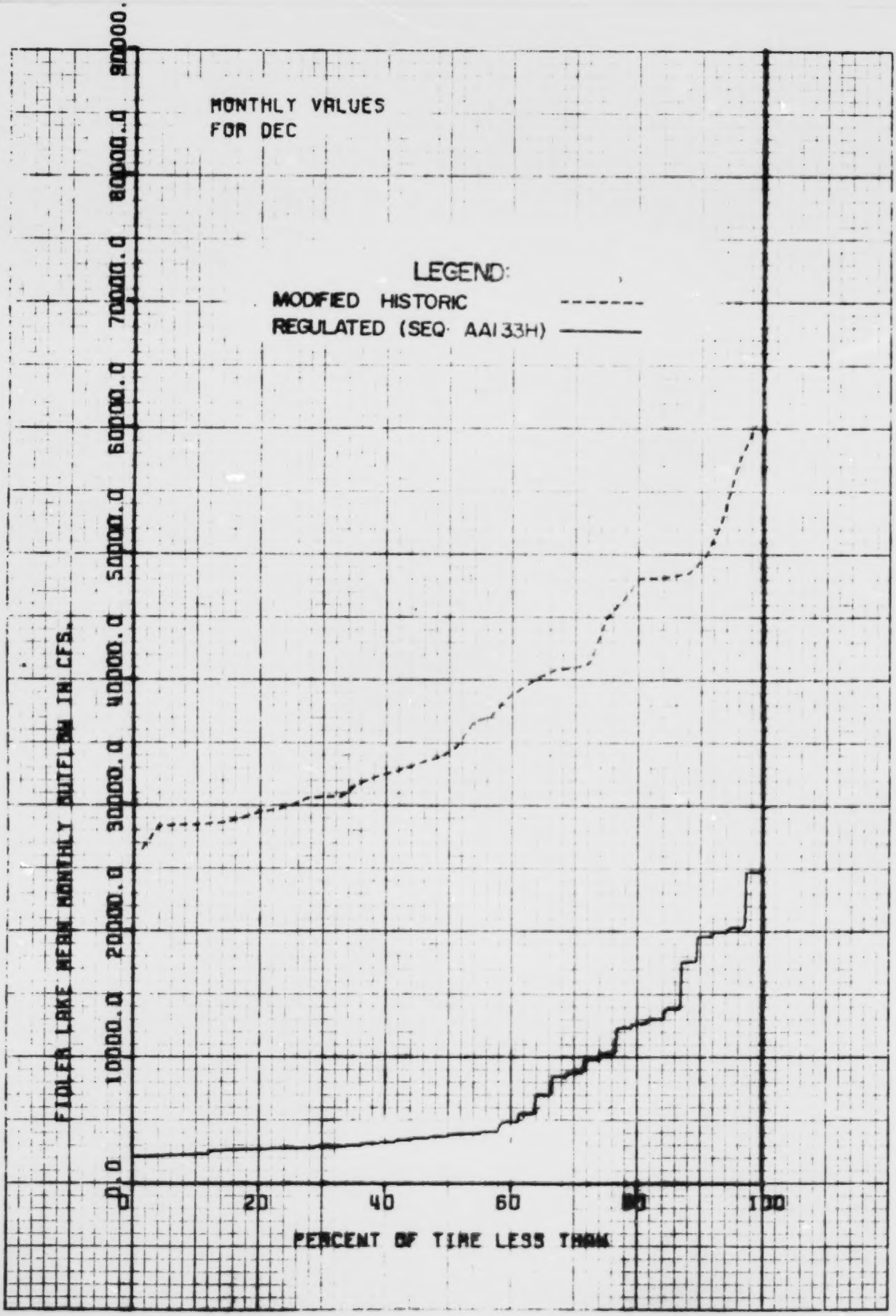

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND
MODIFIED HISTORIC
REGULATED (SEQ AA1334)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI 33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND
MODIFIED HISTORIC
REGULATED (SEQ AA(33H)
FIDLER LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AA133H)
FIDLER LAKE NEAR MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

BILLARD LAKE
LEVELS

BILLIARD LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE LEVEL FLUCTUATIONS IN PERCENT

RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	0	71	0	63	8	63	37	53	58	16	45	3	47	0	63	16	47	29	19	46	5	63	5	79
1 - 2	0	26	0	34	0	24	0	11	24	0	18	0	18	0	11	3	0	16	5	16	3	24	0	13
2 - 4	0	3	0	3	0	5	0	0	3	0	16	0	29	0	8	0	3	5	3	11	5	0	0	3
4 - 6	0	0	0	0	0	0	0	0	0	0	16	0	5	0	0	0	0	0	0	0	0	0	0	0
6 - 8	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
8 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY LEVELS IN FEET

													ANNUAL
MINIMUM	619.27	618.96	618.88	618.69	618.70	619.56	620.21	620.80	620.84	620.15	619.71	619.39	618.69
AVERAGE	622.03	621.22	620.56	620.21	620.74	622.61	624.20	624.76	624.49	623.84	623.37	622.75	622.57
MAXIMUM	628.06	626.18	623.74	622.17	624.37	630.79	633.31	633.23	631.70	631.36	630.54	629.34	633.31

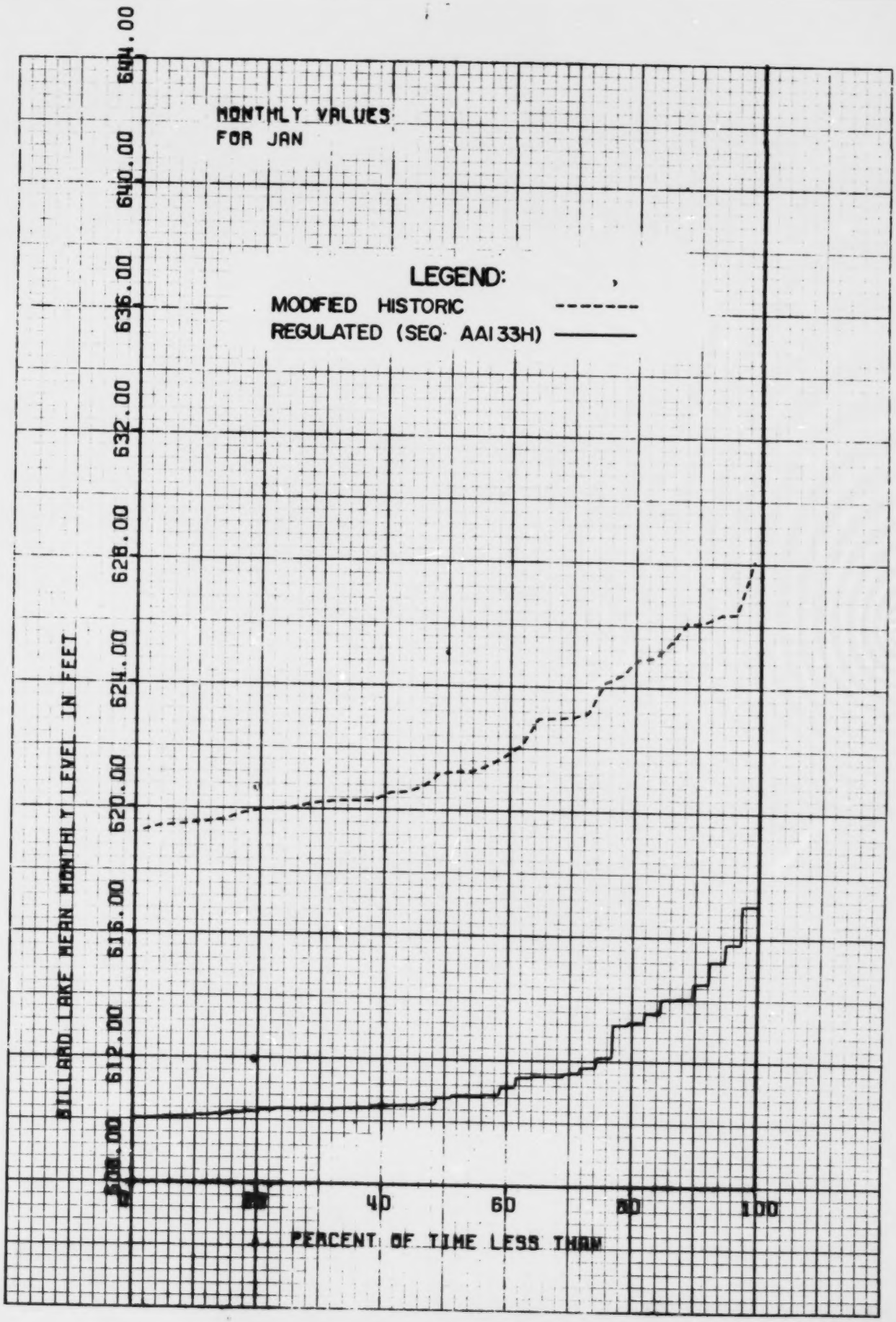
BILLIARD LAKE - REGULATED CONDITIONS

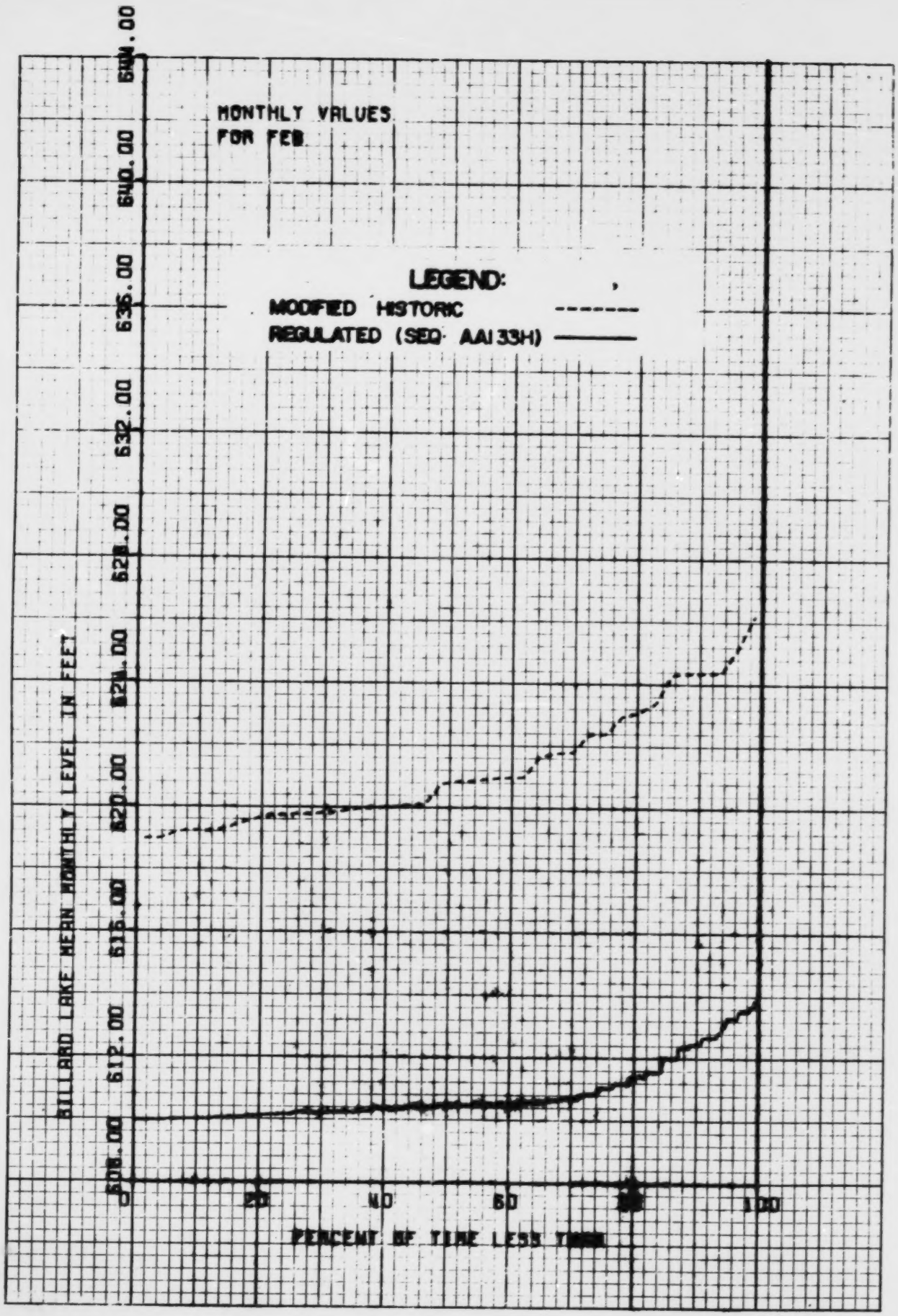
AVERAGE LEVEL FLUCTUATIONS IN PERCENT

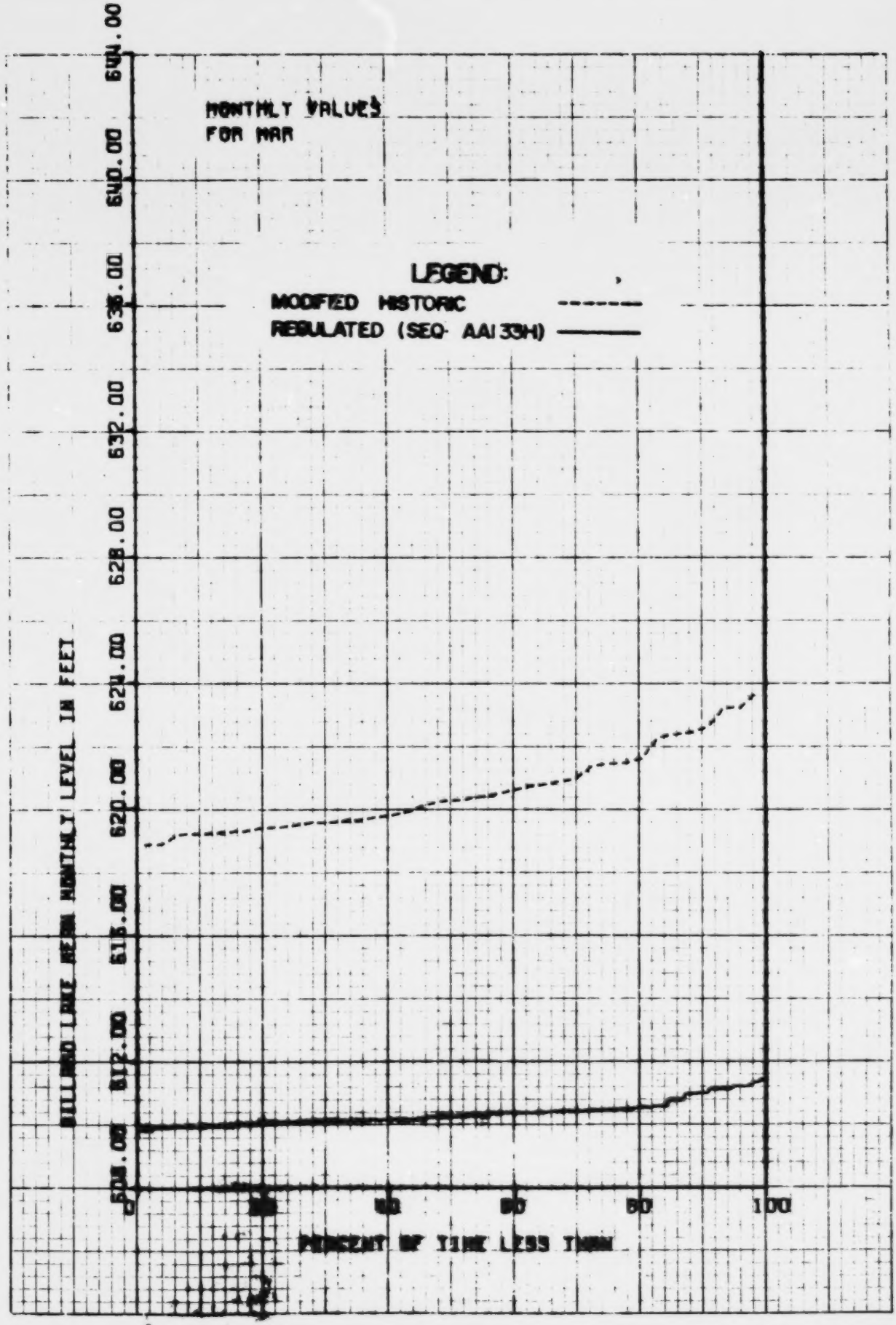
RANGE IN FEET	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 1	12	49	2	70	0	82	16	77	23	35	10	4	21	21	13	33	2	4	8	22	15	61	24	34
1 - 2	0	20	0	15	0	13	3	1	0	0	5	0	21	15	5	18	4	33	8	39	0	10	2	24
2 - 4	0	19	0	13	0	5	2	0	7	0	19	0	14	9	3	23	0	51	3	18	0	10	0	13
4 - 6	0	0	0	0	0	0	0	0	15	0	32	0	0	0	0	5	0	2	3	0	0	2	0	2
6 - 8	0	0	0	0	0	0	0	0	13	0	17	0	0	0	0	0	0	2	0	0	0	2	0	0
8 -	0	0	0	0	0	0	0	0	7	0	13	0	0	0	0	0	0	0	0	0	0	1	0	0

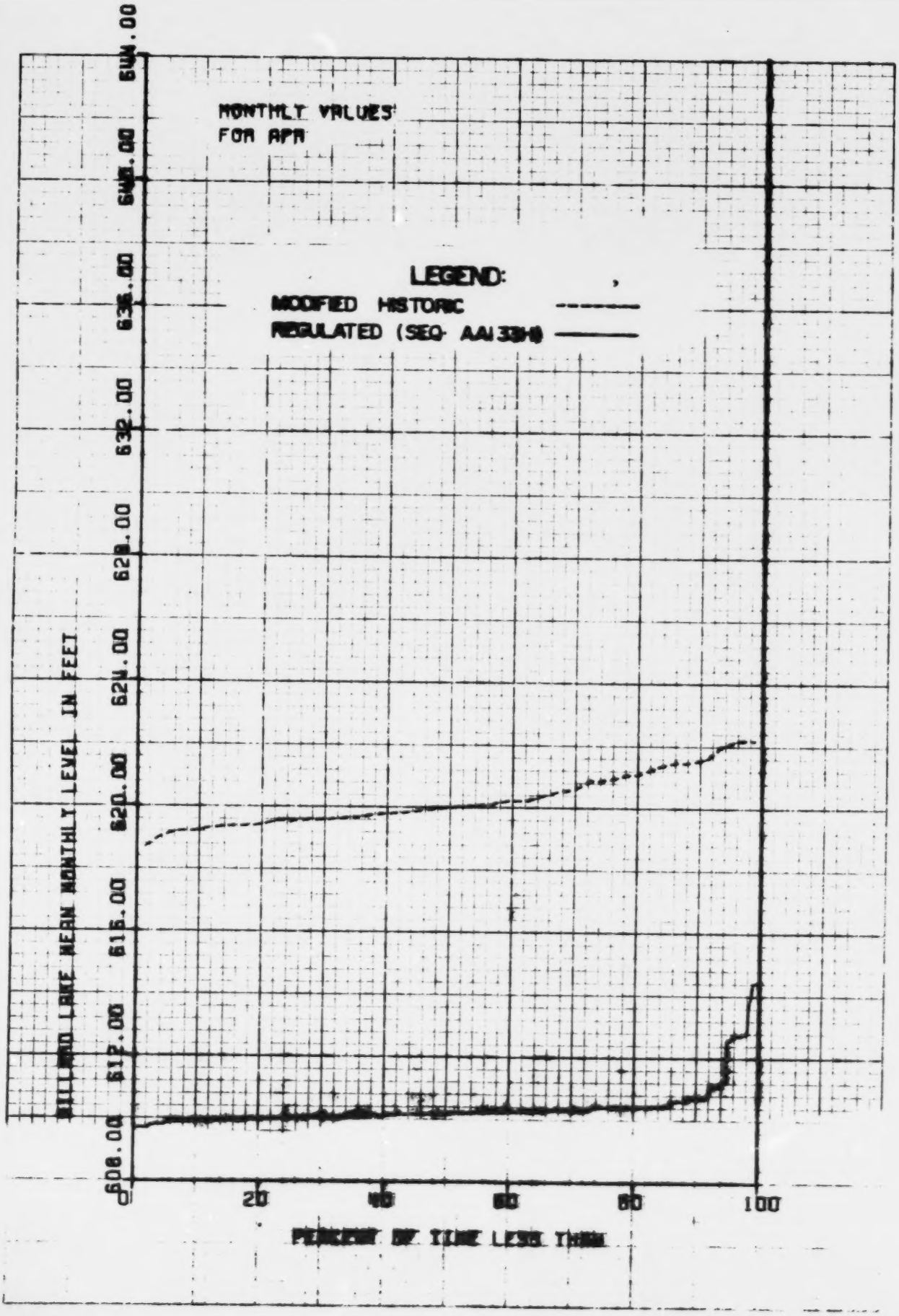
MEAN MONTHLY LEVELS IN FEET

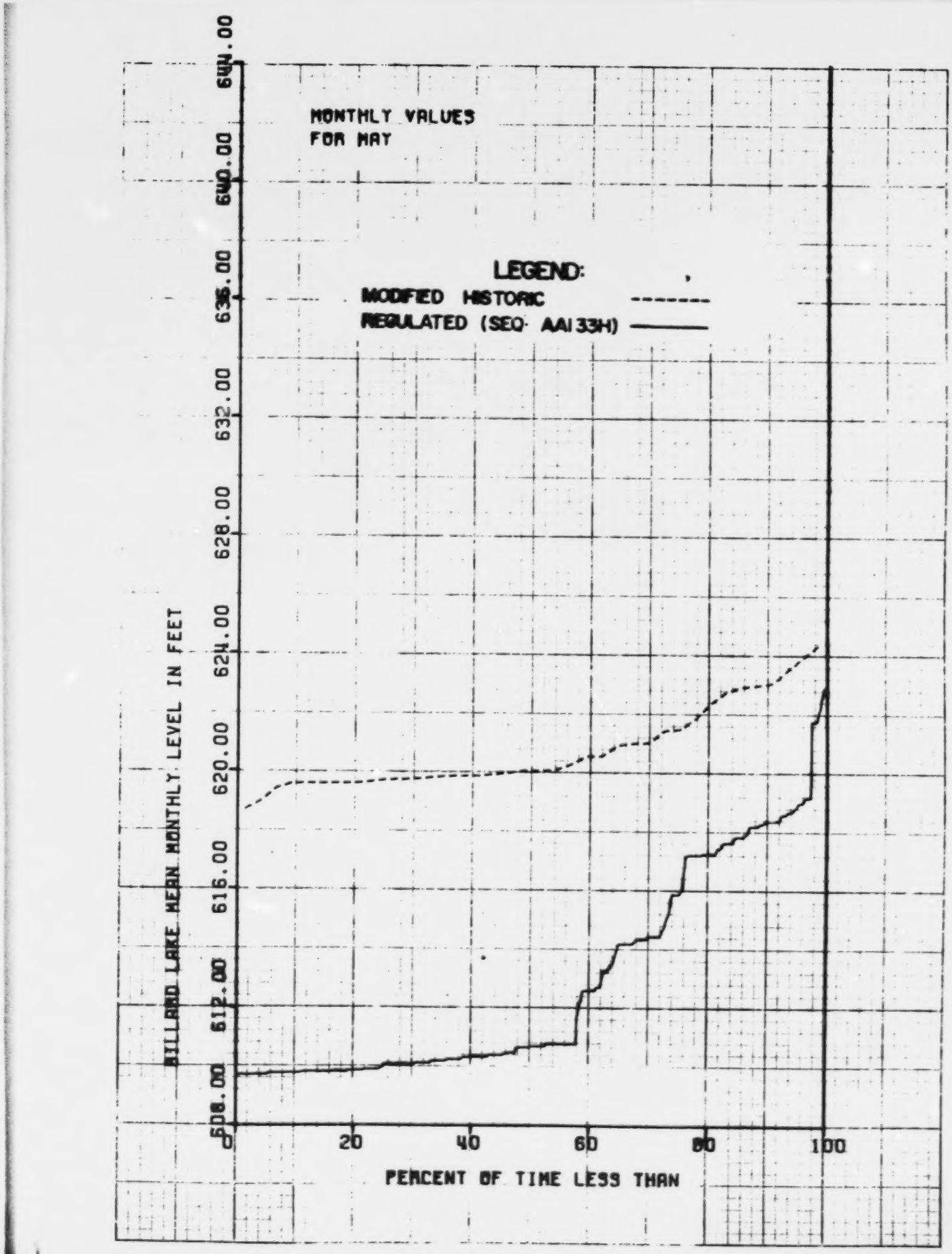
													ANNUAL
MINIMUM	610.01	609.93	609.81	609.67	609.68	609.62	609.99	610.34	609.87	609.93	609.90	610.01	609.62
AVERAGE	611.55	610.77	610.32	610.33	612.81	617.69	617.90	616.82	614.60	614.19	613.31	612.47	613.56
MAXIMUM	617.01	613.85	611.43	614.12	622.85	631.79	628.61	624.99	622.04	630.74	622.69	619.13	631.79

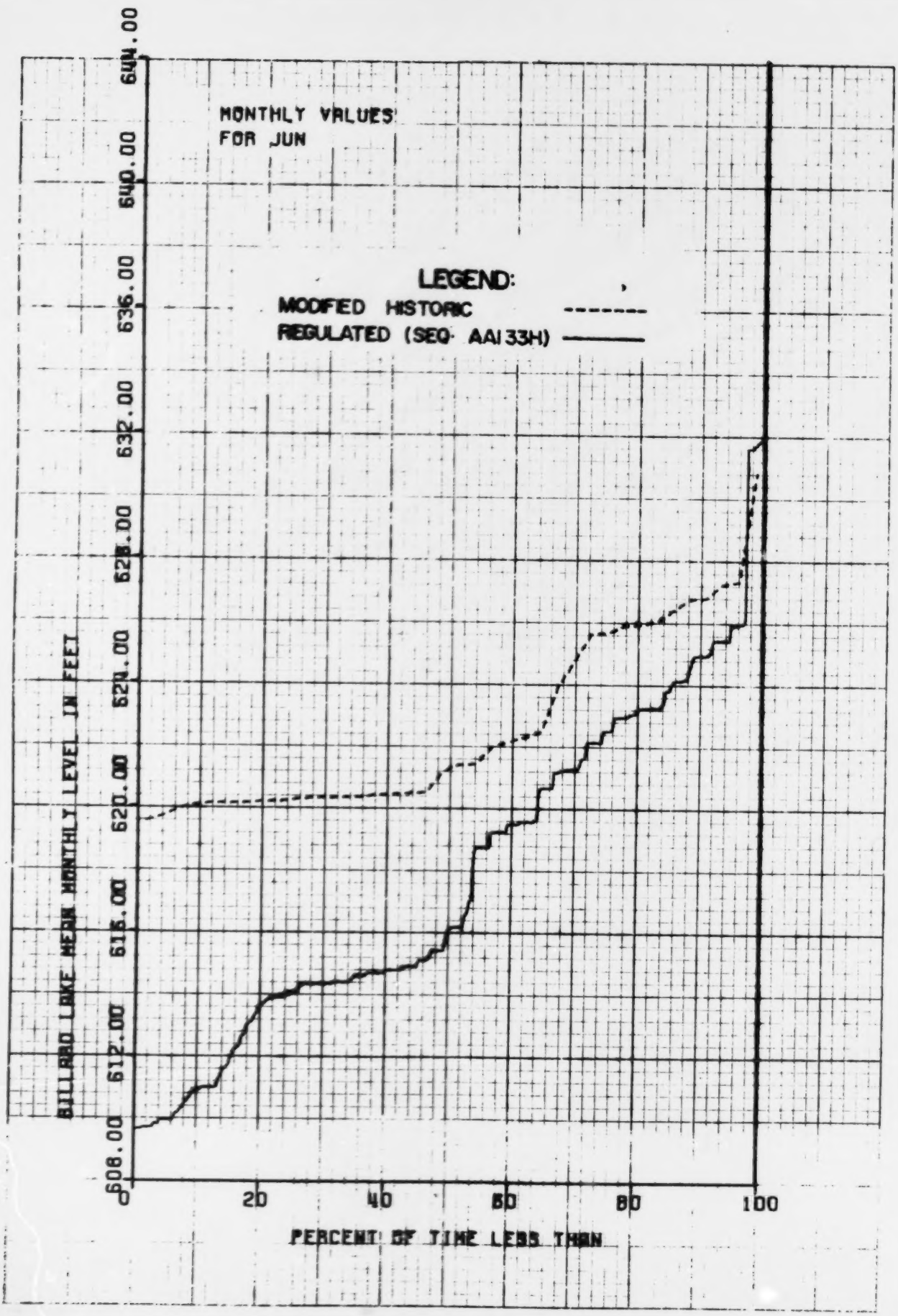

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
644.00
640.00
636.00
632.00
628.00
624.00
620.00
616.00
612.00
608.00
40
60
80
100
PERCENT OF TIME LESS THAN

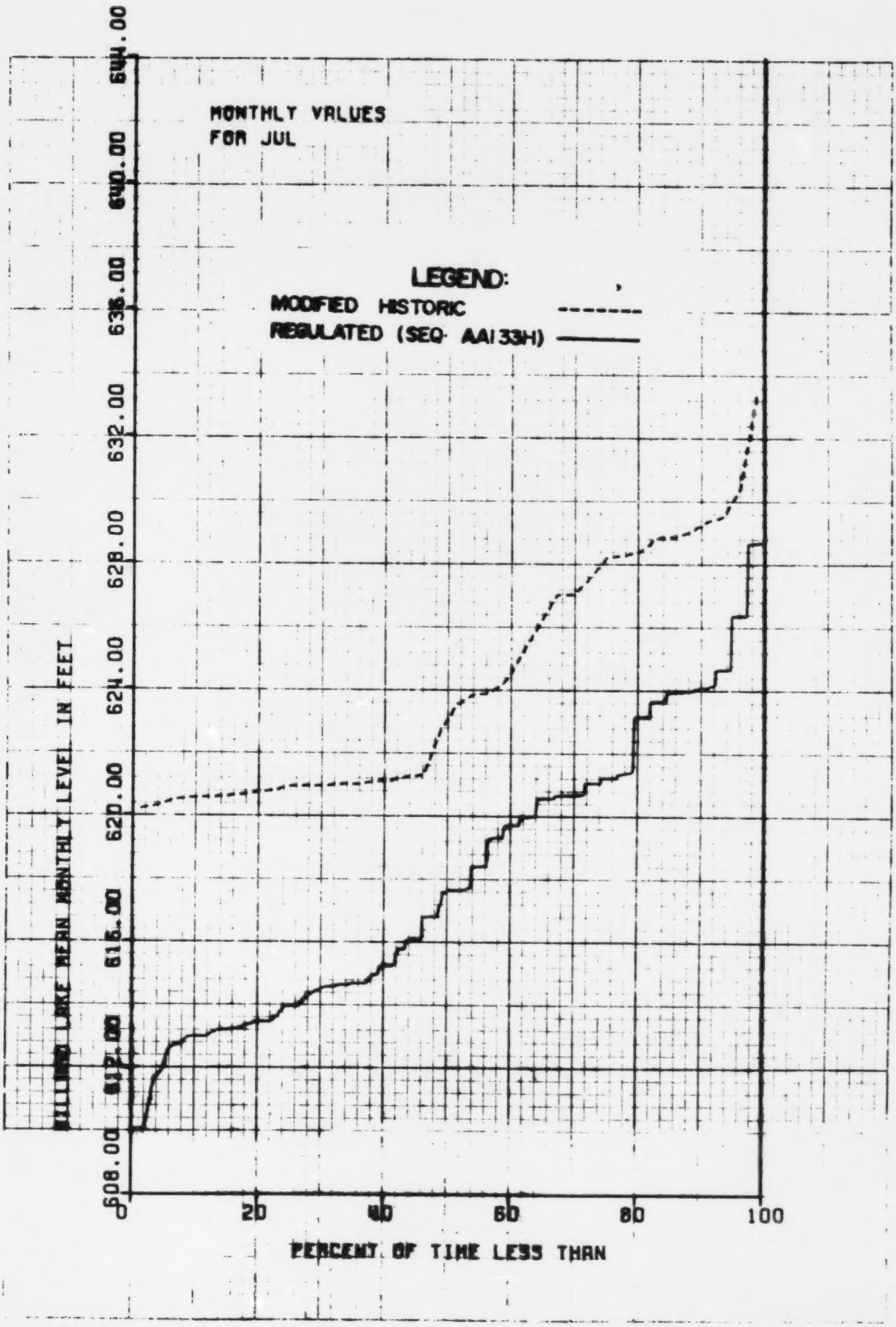

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
PERCENT OF TIME LESS THAN

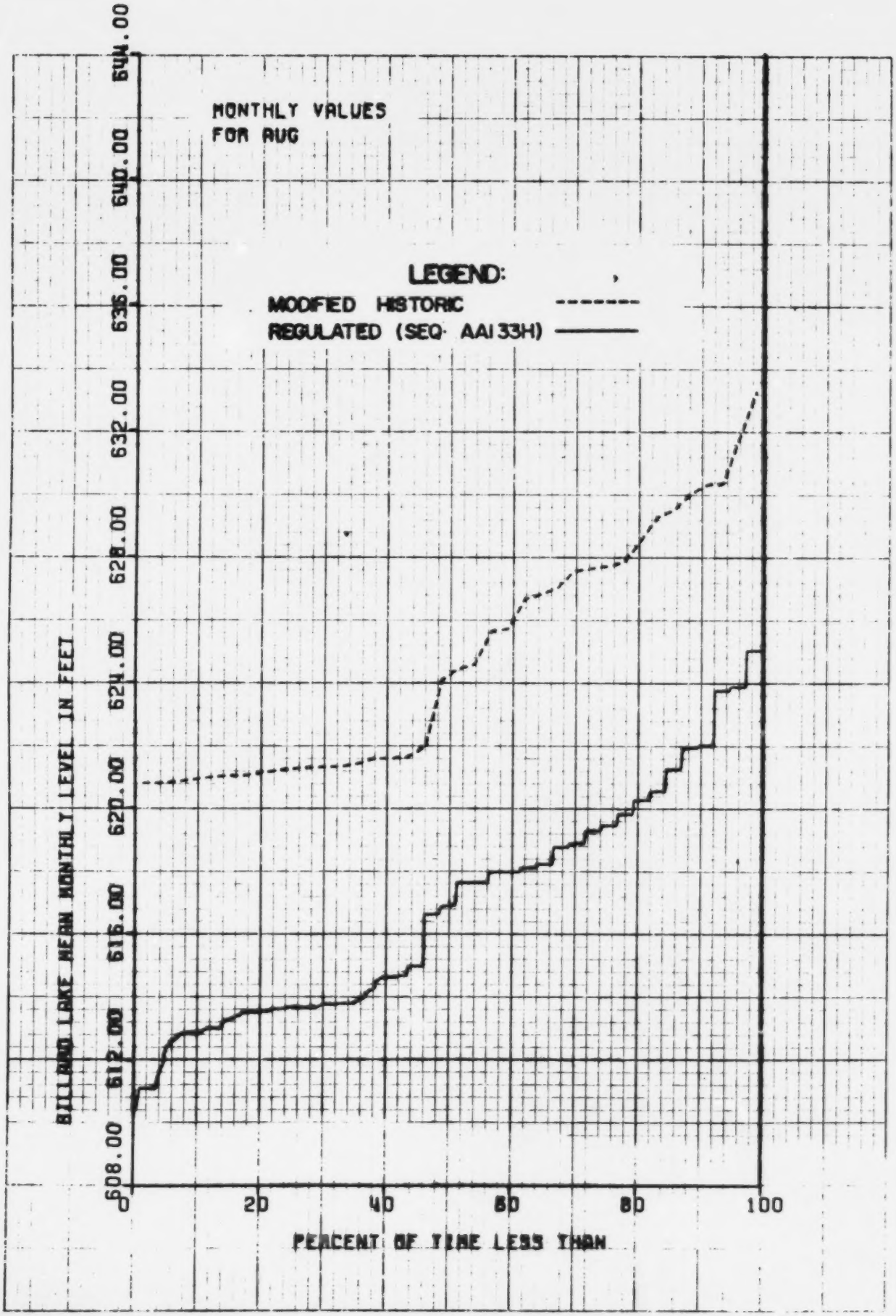

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AA133H)
644.00
640.00
636.00
632.00
628.00
624.00
620.00
616.00
612.00
608.00
100
PERCENT OF TIME LESS THAN

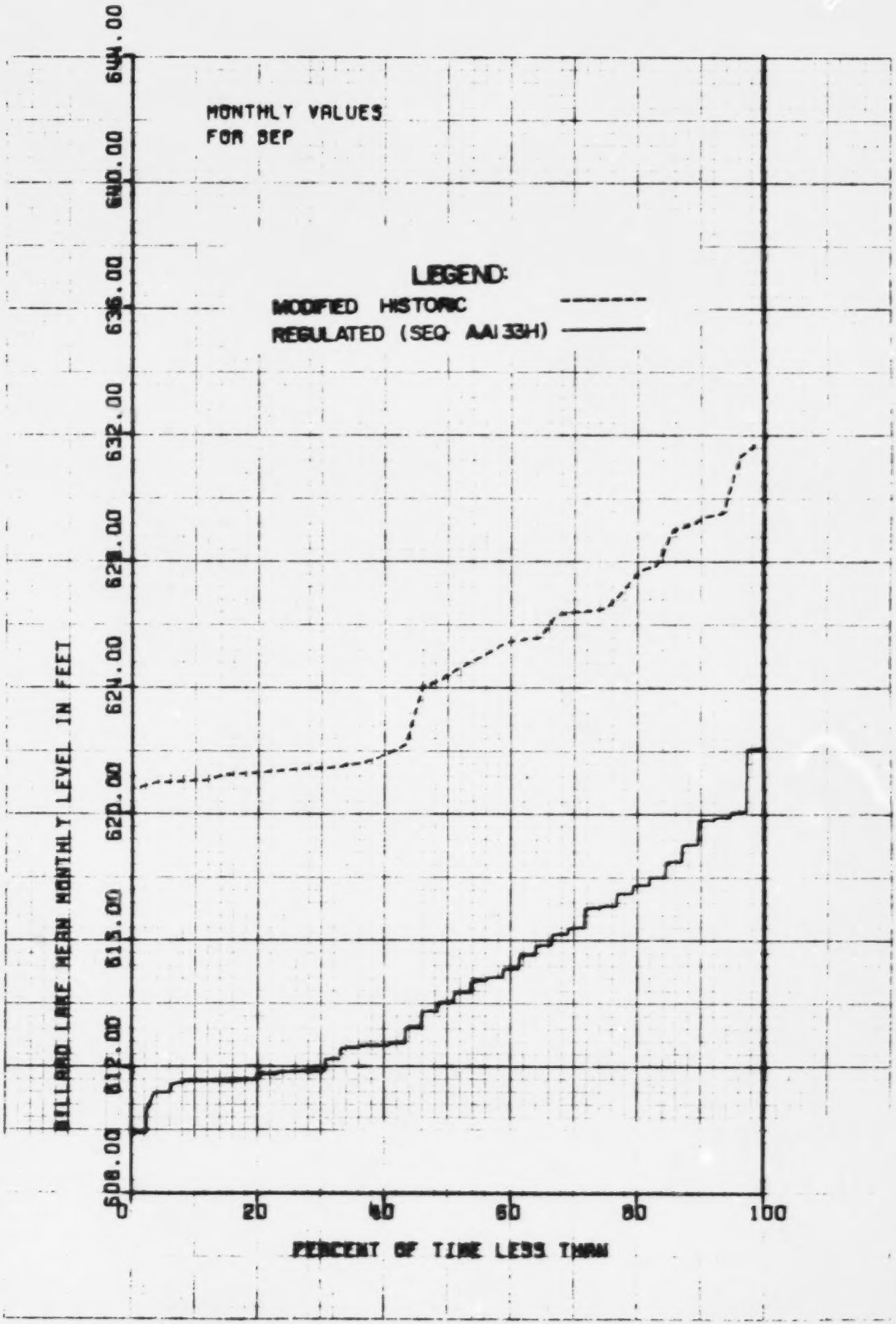

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 3340)
MEAN MONTHLY LAKE LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
644.00
20
40
60
80
100
PERCENT OF TIME LESS THAN

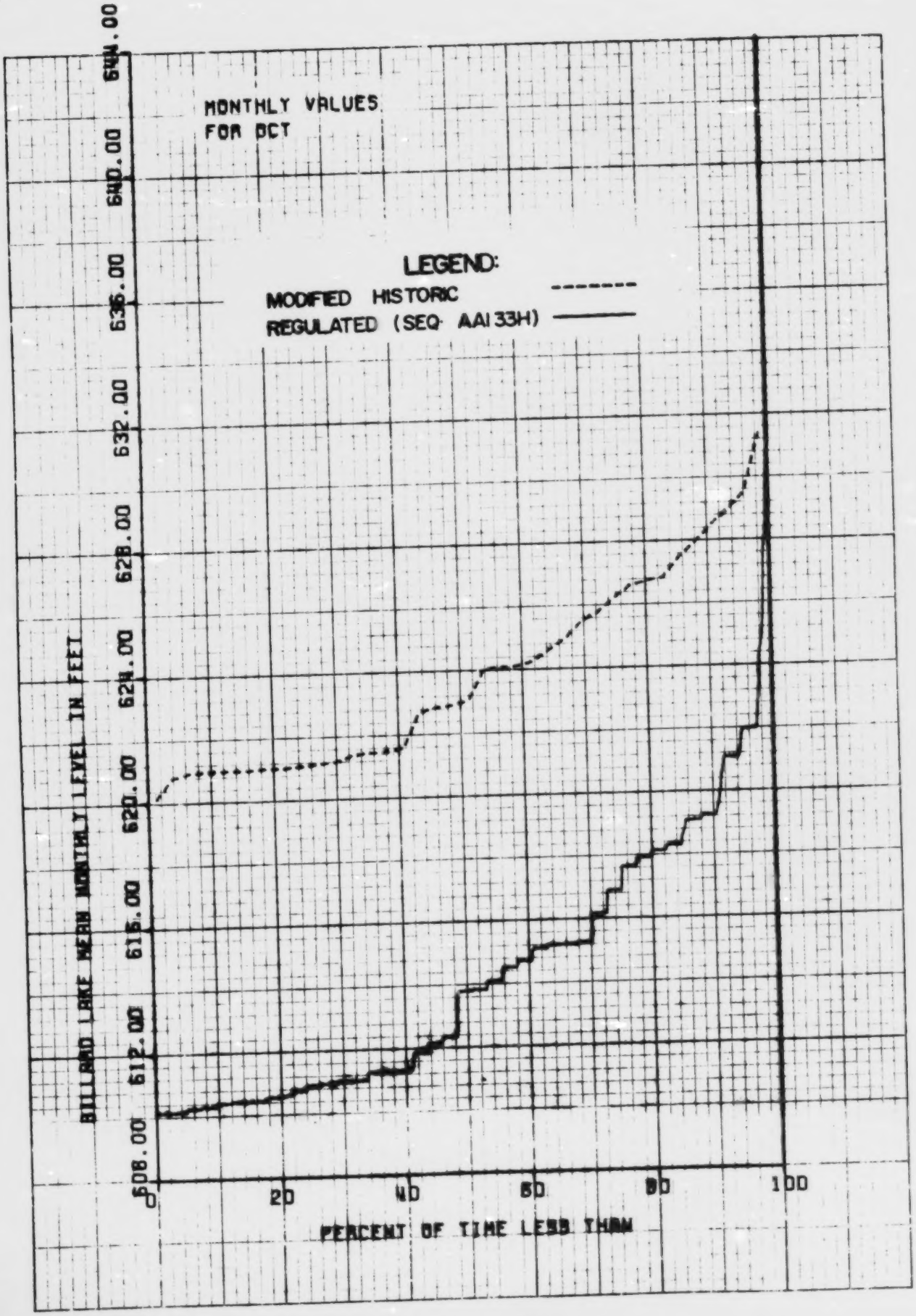

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

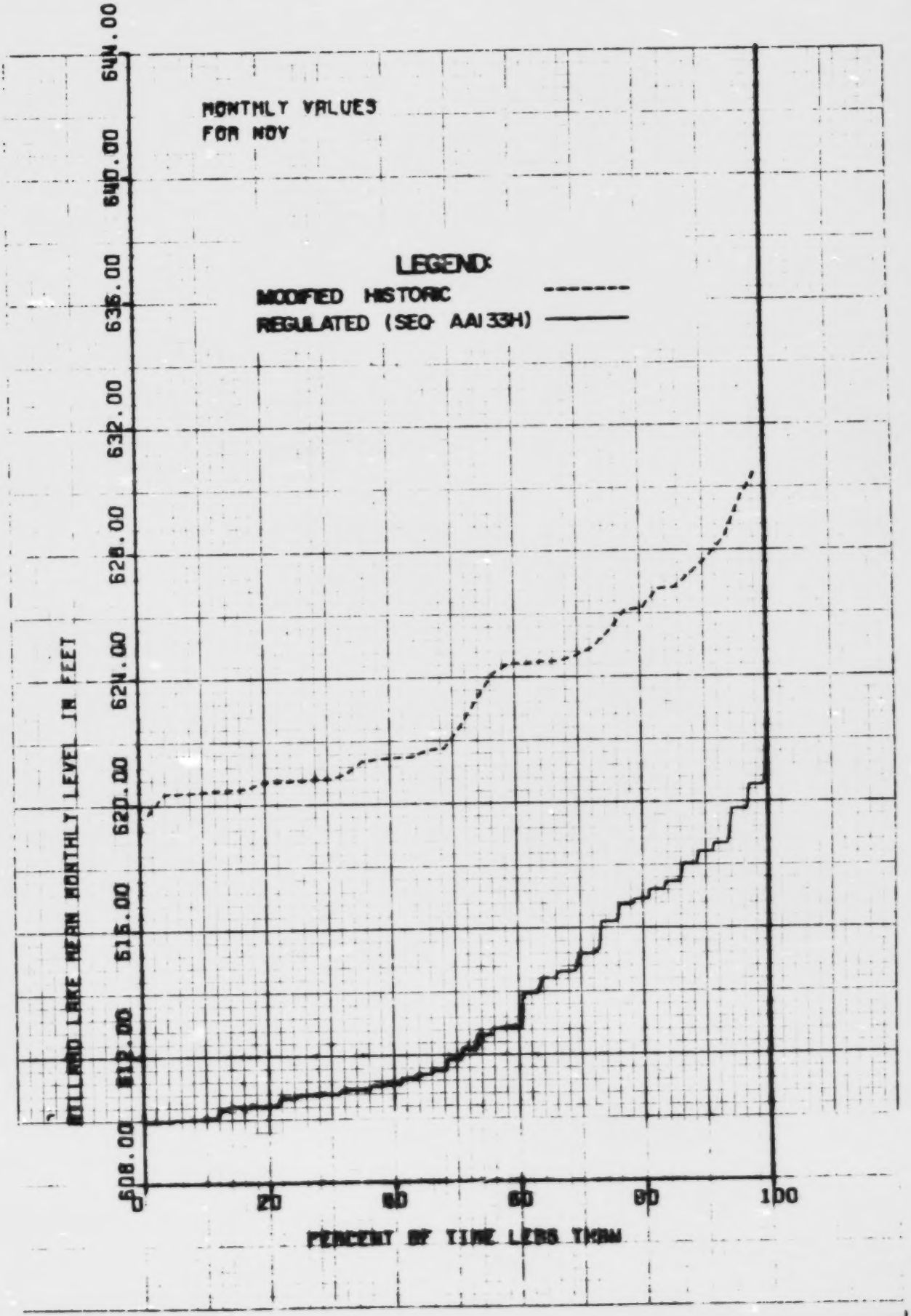

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLRBO LAKE MEAN MONTHLY LEVEL IN FEET
644.00
640.00
636.00
632.00
628.00
624.00
620.00
616.00
612.00
608.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

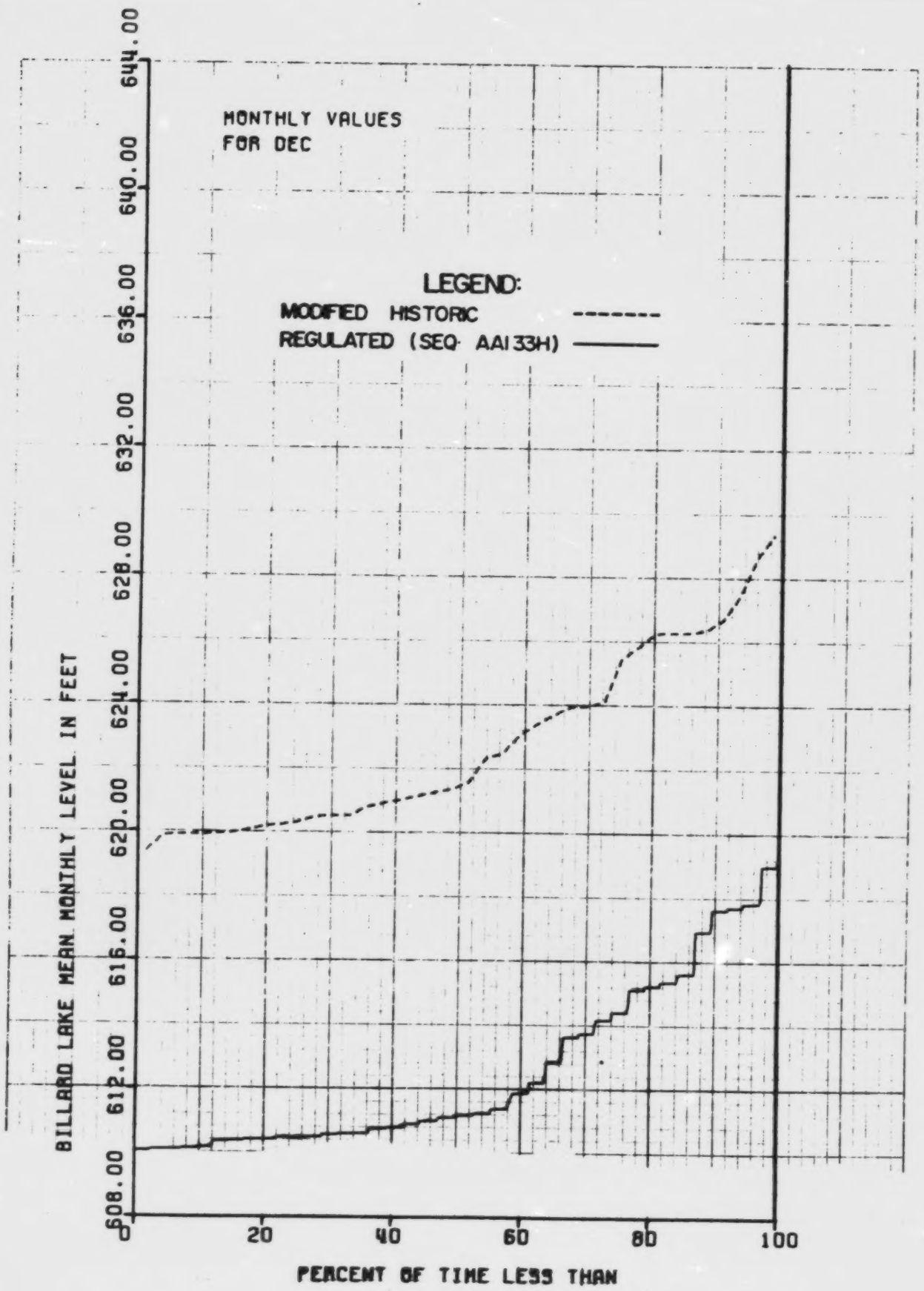

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AA133H)
644.00
640.00
636.00
632.00
628.00
624.00
620.00
616.00
612.00
608.00
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
644.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
644.00
640.00
636.00
632.00
628.00
624.00
620.00
616.00
612.00
608.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
644.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
MILLARD LAKE MEAN MONTHLY LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
644.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)
BILLARD LAKE MEAN MONTHLY LEVEL IN FEET
608.00
612.00
616.00
620.00
624.00
628.00
632.00
636.00
640.00
644.00
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

Billard Lake
Outflows

BILLIARD LAKE - MODIFIED HISTORIC CONDITIONS

AVERAGE FLOW FLUCTUATIONS IN PERCENT

RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	0	87	0	87	8	84	34	66	76	16	50	3	61	0	68	16	47	29	24	51	8	82	5	87
5 - 10	0	13	0	13	0	8	0	0	8	0	21	0	16	0	13	3	3	21	0	22	5	5	0	8
10 - 20	0	0	0	0	0	0	0	0	0	0	24	0	24	0	0	0	0	0	3	0	0	0	0	0
20 - 30	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN MONTHLY FLOWS IN CFS.

													ANNUAL
MINIMUM	26,160	24,980	24,640	23,940	23,960	27,250	29,730	31,940	32,120	29,490	27,810	26,620	23,940
AVERAGE	35,433	32,809	30,792	29,696	31,322	37,435	43,096	45,096	43,868	41,606	39,979	37,855	37,415
MAXIMUM	55,510	48,110	40,660	36,520	42,310	66,900	77,780	77,480	70,840	69,350	65,810	60,650	77,780

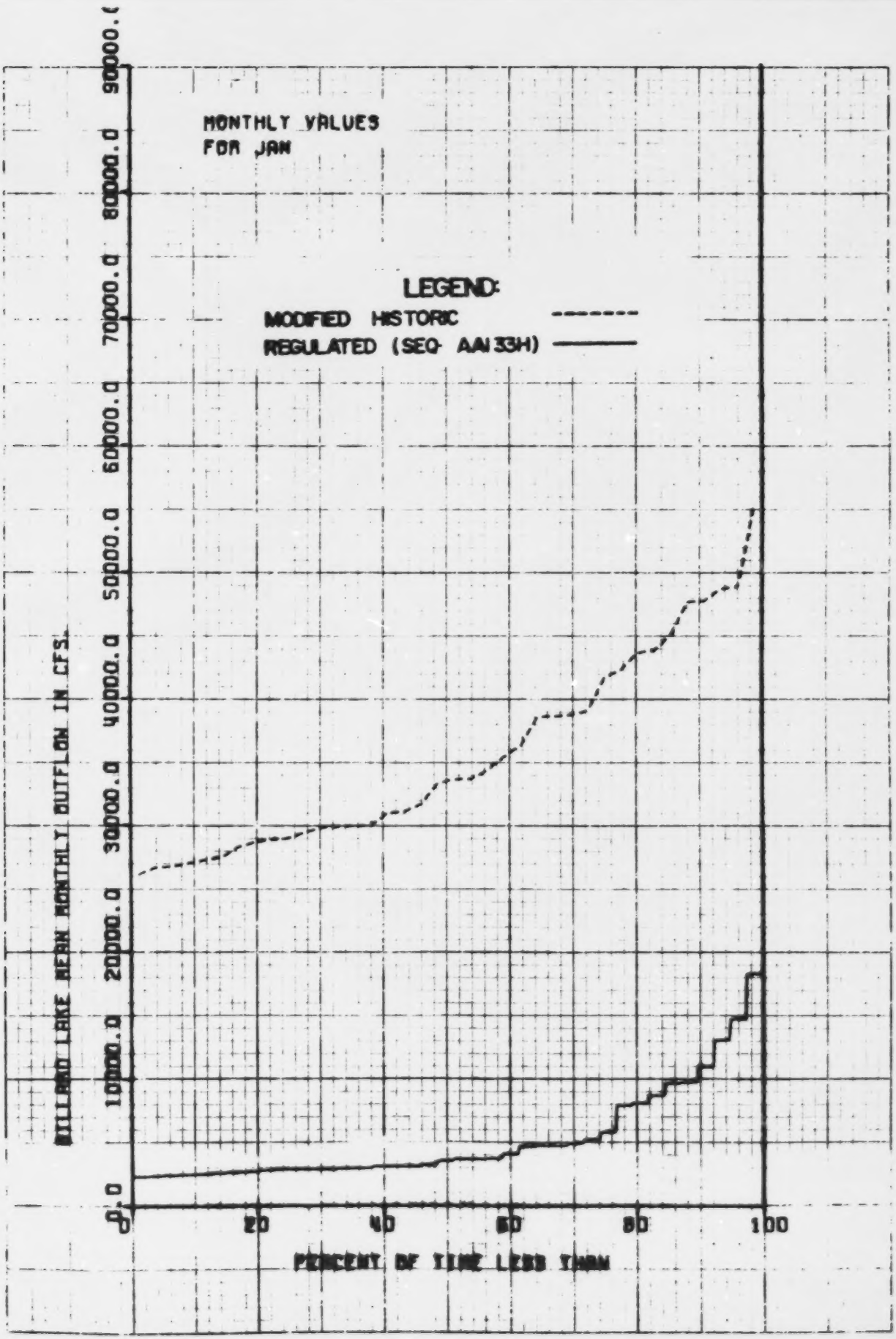
BILLIARD LAKE - REGULATED CONDITIONS

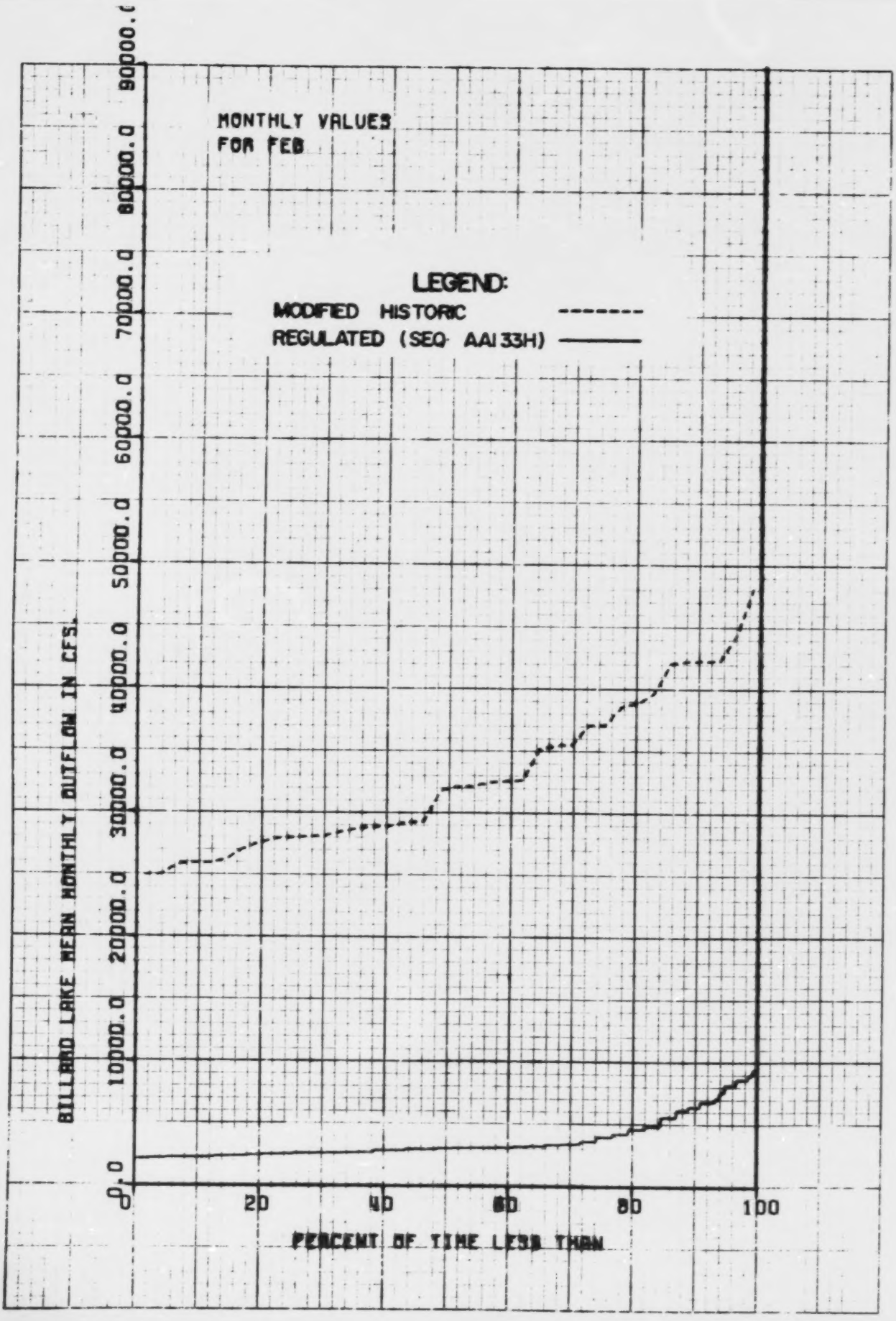
AVERAGE FLOW FLUCTUATIONS IN PERCENT

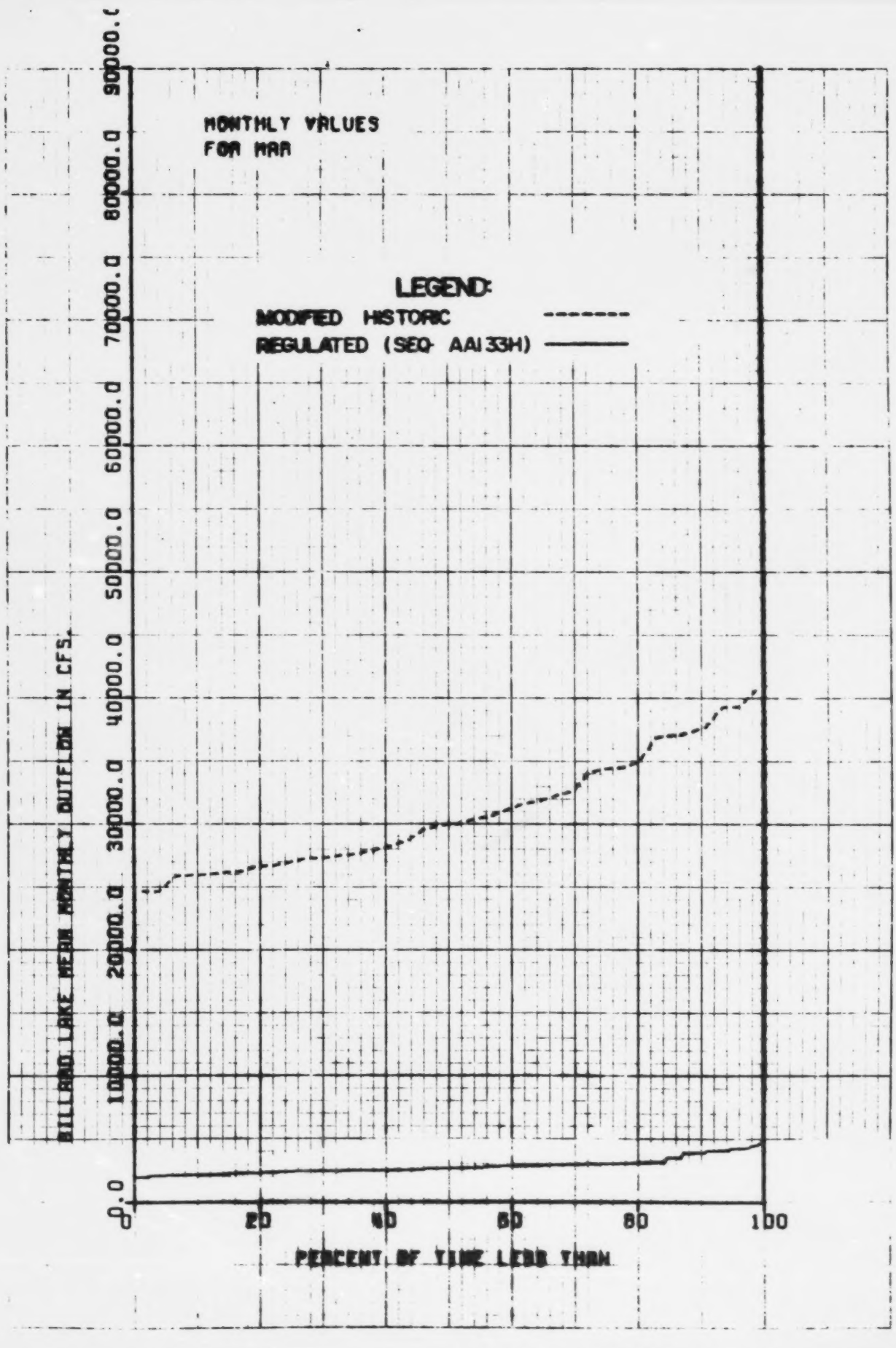
RANGE IN 1000 cfs	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0 - 5	10	72	2	87	0	99	20	79	27	35	15	4	47	31	19	48	4	40	16	64	15	70	27	58
5 - 10	0	19	0	11	0	1	2	0	12	0	33	0	8	11	2	15	2	28	0	13	0	10	0	10
10 - 20	0	0	0	0	0	0	0	0	21	0	18	0	0	2	0	15	0	23	5	3	0	2	0	4
20 - 30	0	0	0	0	0	0	0	0	3	0	21	0	0	0	0	0	0	2	0	0	0	3	0	0
30 - 40	0	0	0	0	0	0	0	0	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
40 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

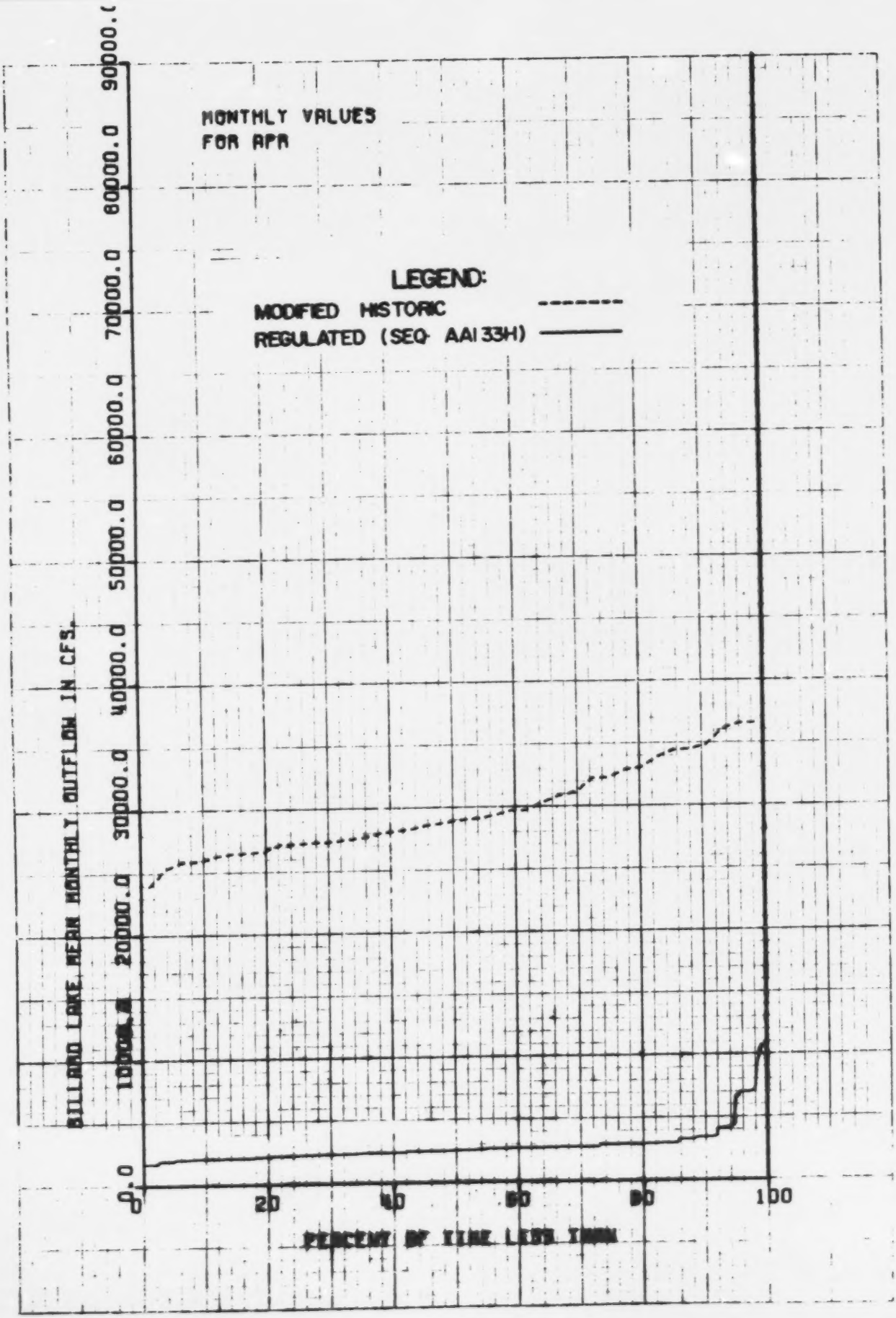
MEAN MONTHLY FLOWS IN CFS.

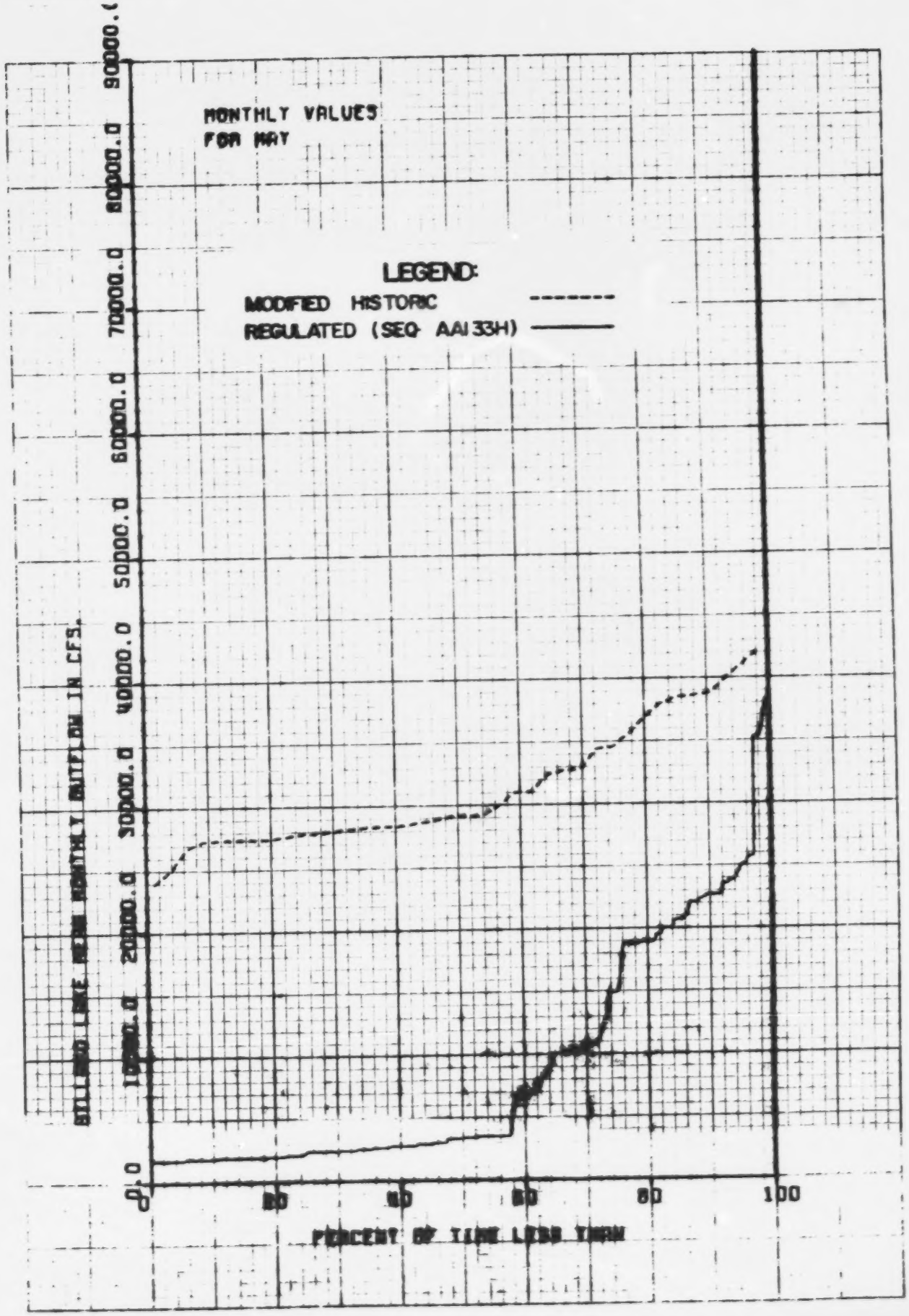
													ANNUAL
MINIMUM	2,190	2,060	1,870	1,630	1,640	1,550	2,150	2,740	1,960	2,060	2,020	2,200	1,550
AVERAGE	5,105	3,512	2,720	2,755	8,681	22,208	22,397	18,795	12,497	12,023	9,552	7,329	10,631
MAXIMUM	18,230	9,300	4,570	10,700	38,210	71,260	57,720	43,950	36,160	66,680	37,930	25,590	71,260

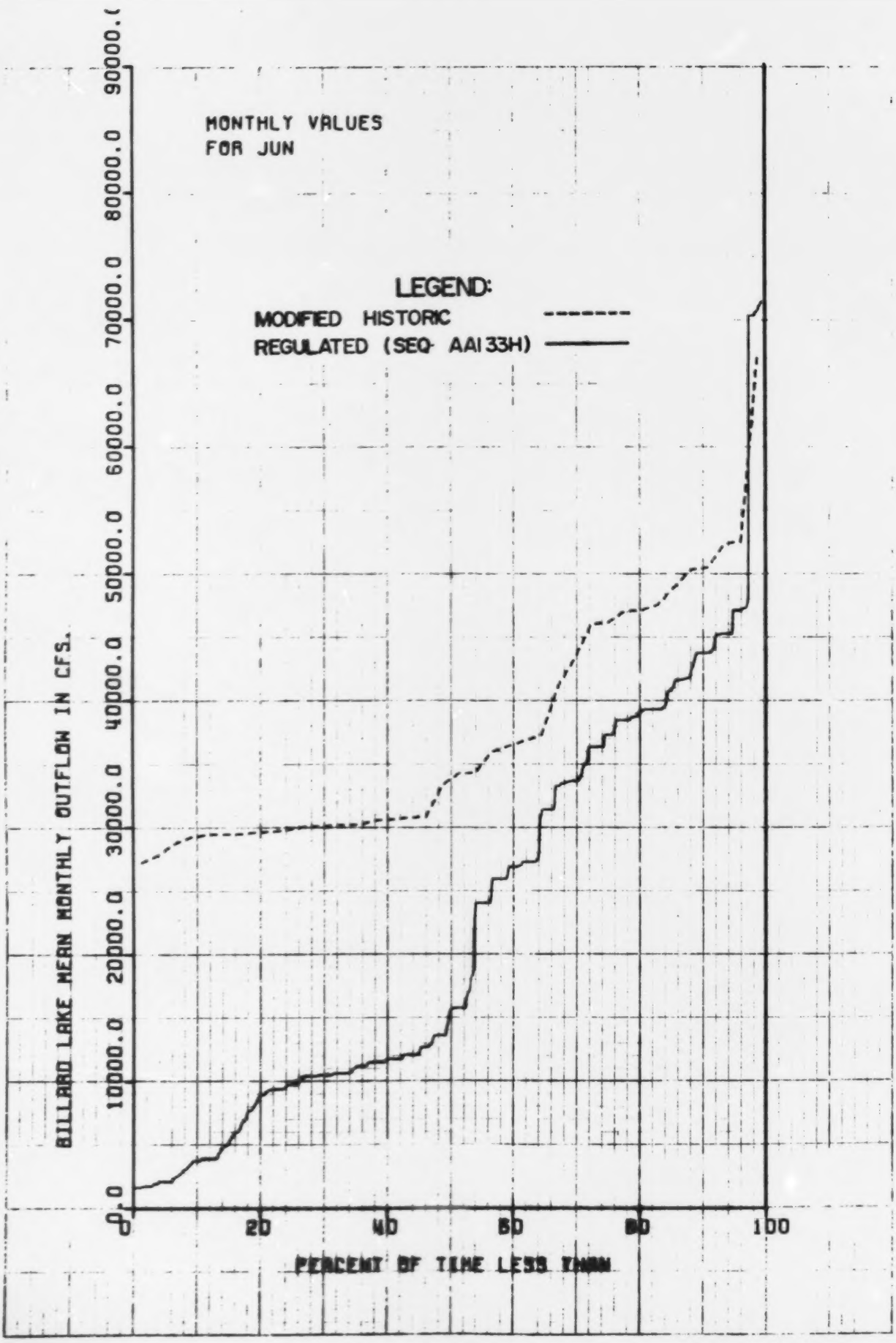

MONTHLY VALUES
FOR JAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

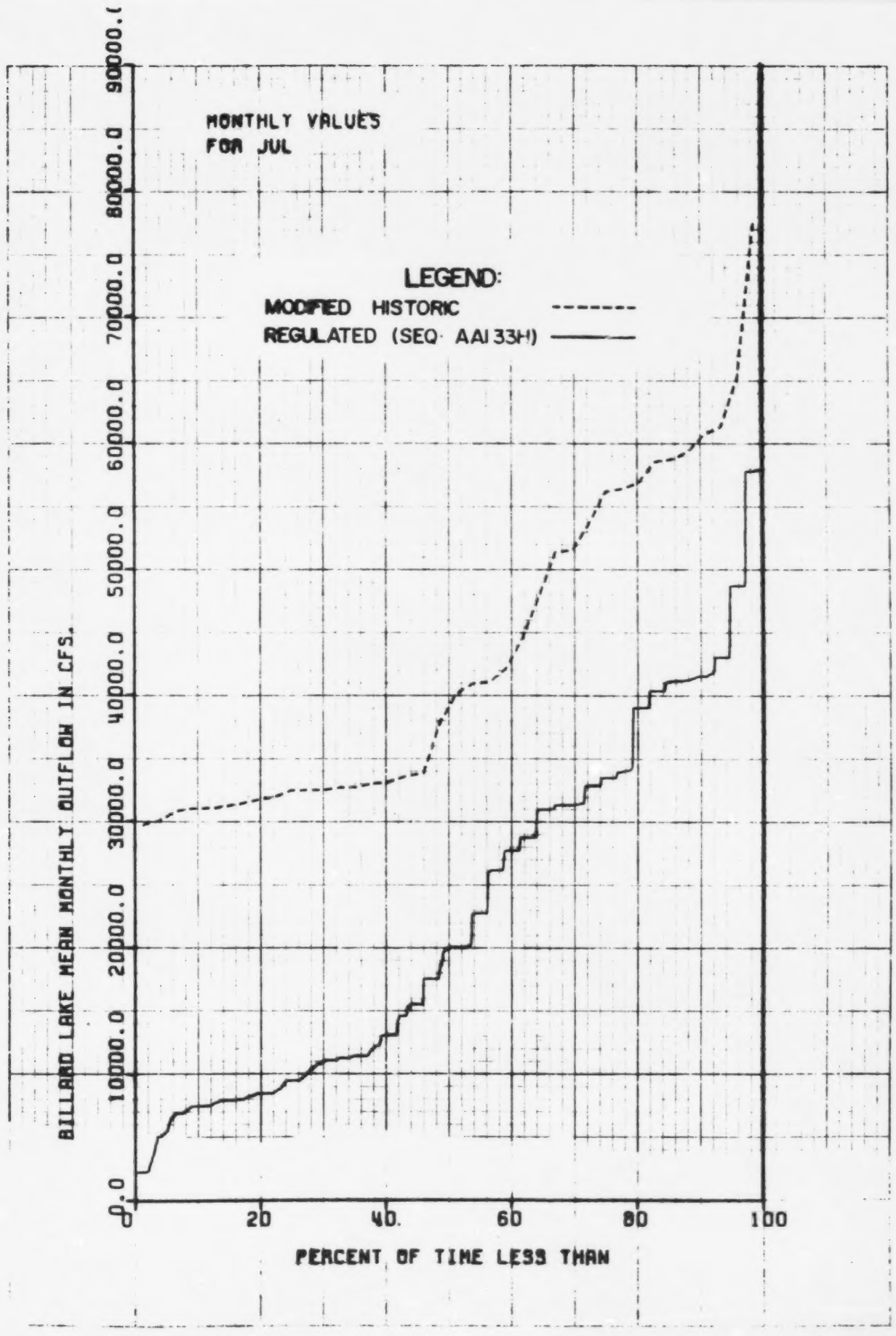

MONTHLY VALUES
FOR FEB
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AA133H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

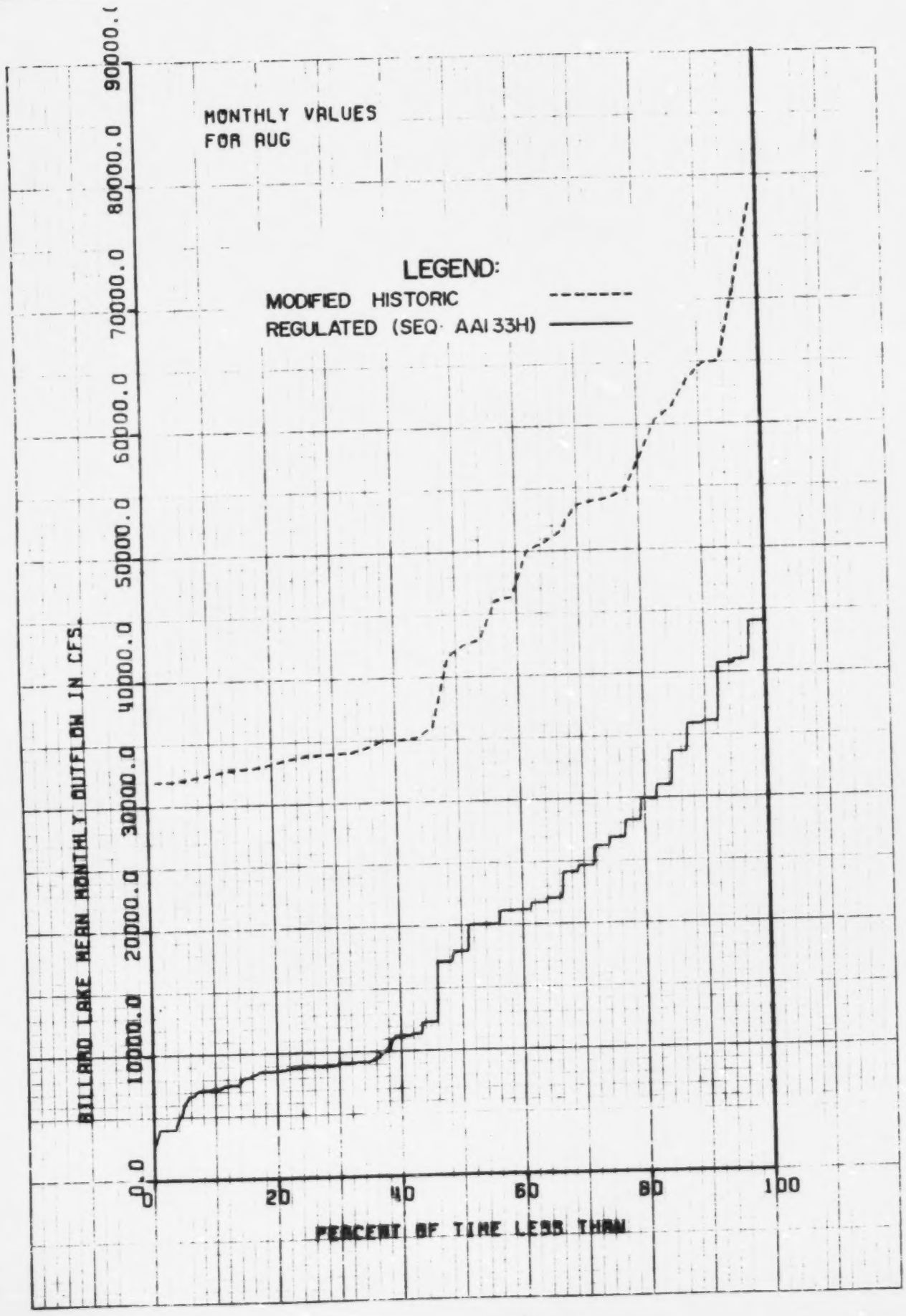

MONTHLY VALUES
FOR MAR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN

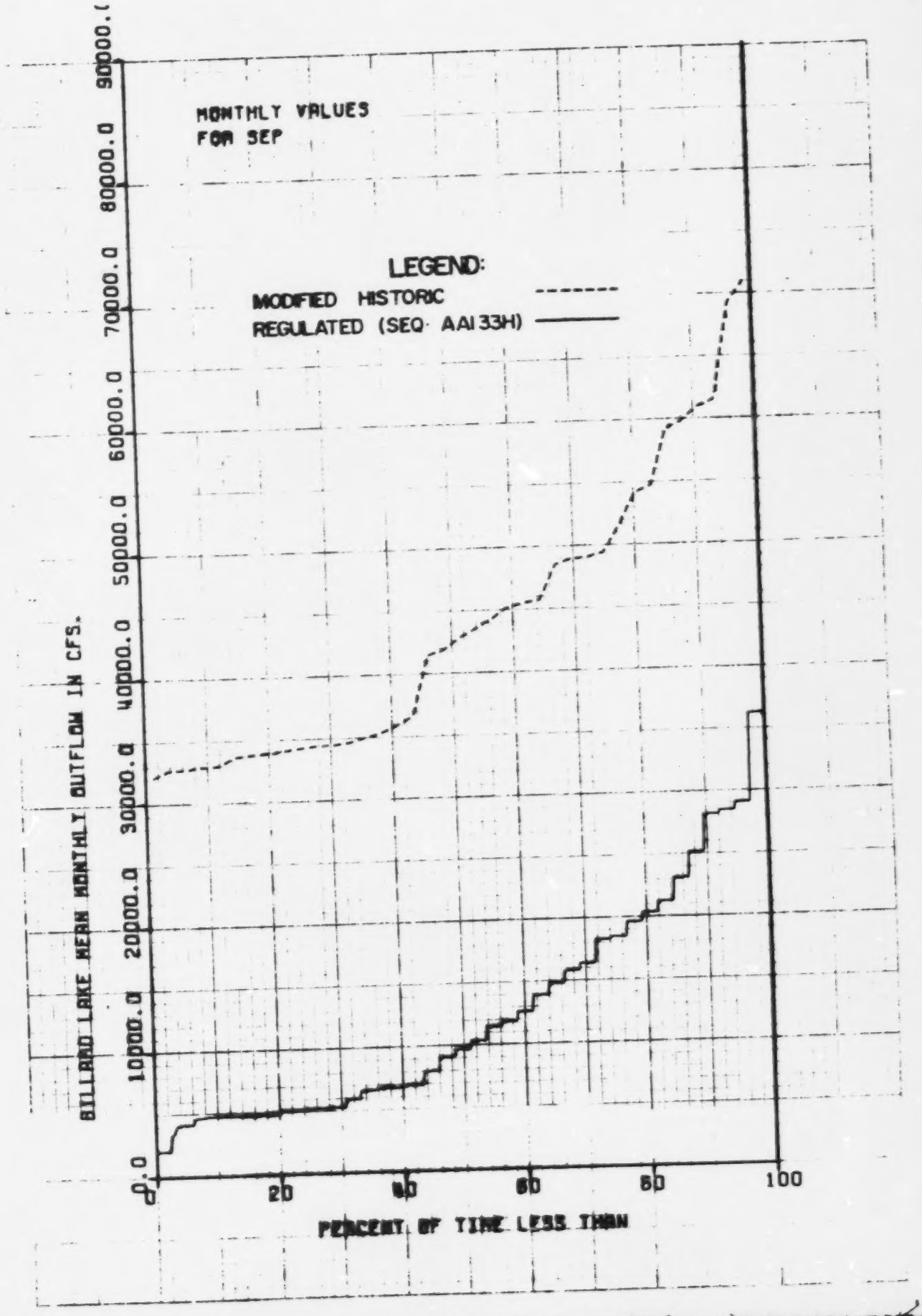

MONTHLY VALUES
FOR APR
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI33H)
BILLARD LAKE NEAR MONTHLY OUTFLOW IN CFS.
0.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

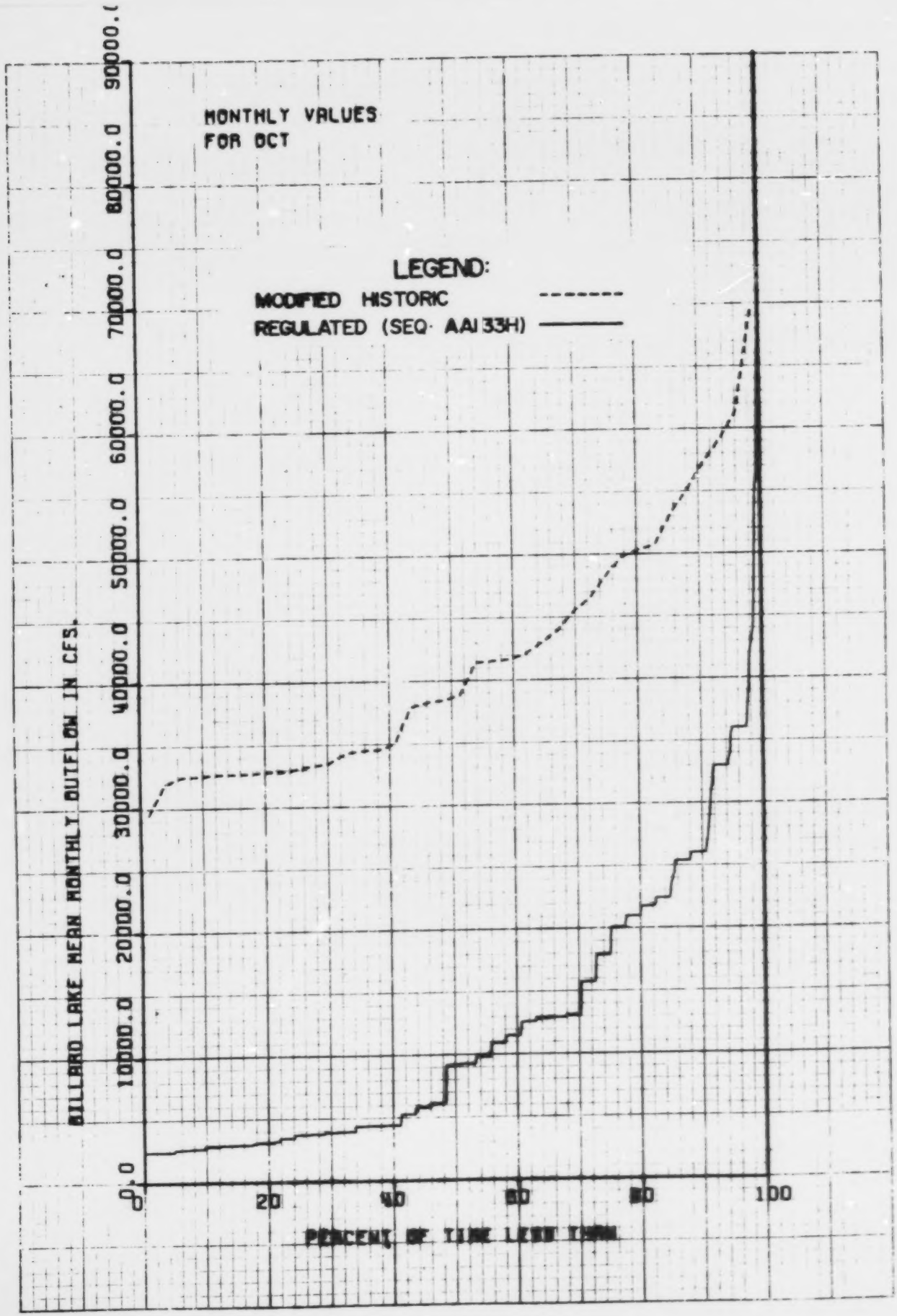

MONTHLY VALUES
FOR MAY
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ AAI33H)
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

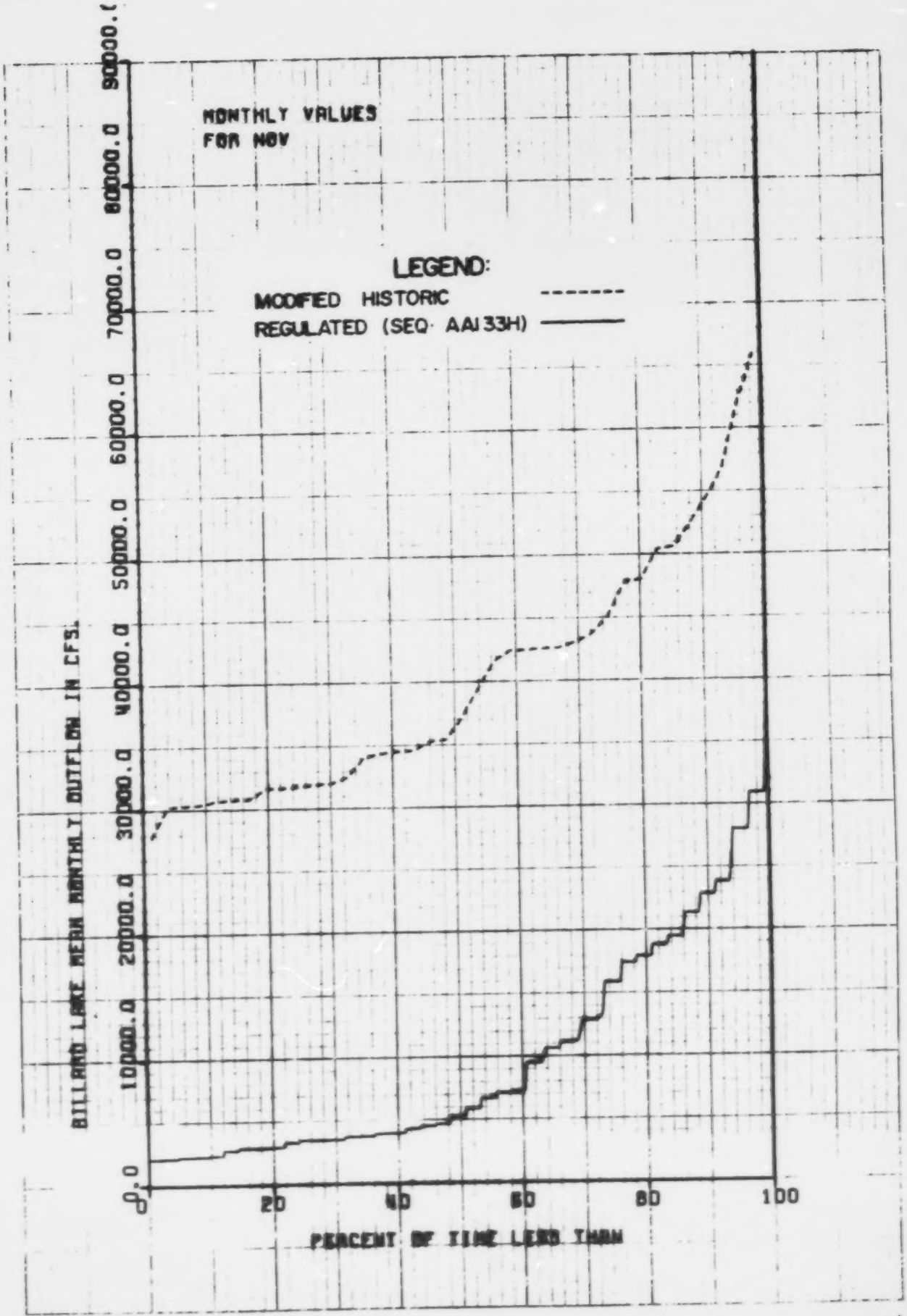

MONTHLY VALUES
FOR JUN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ- AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

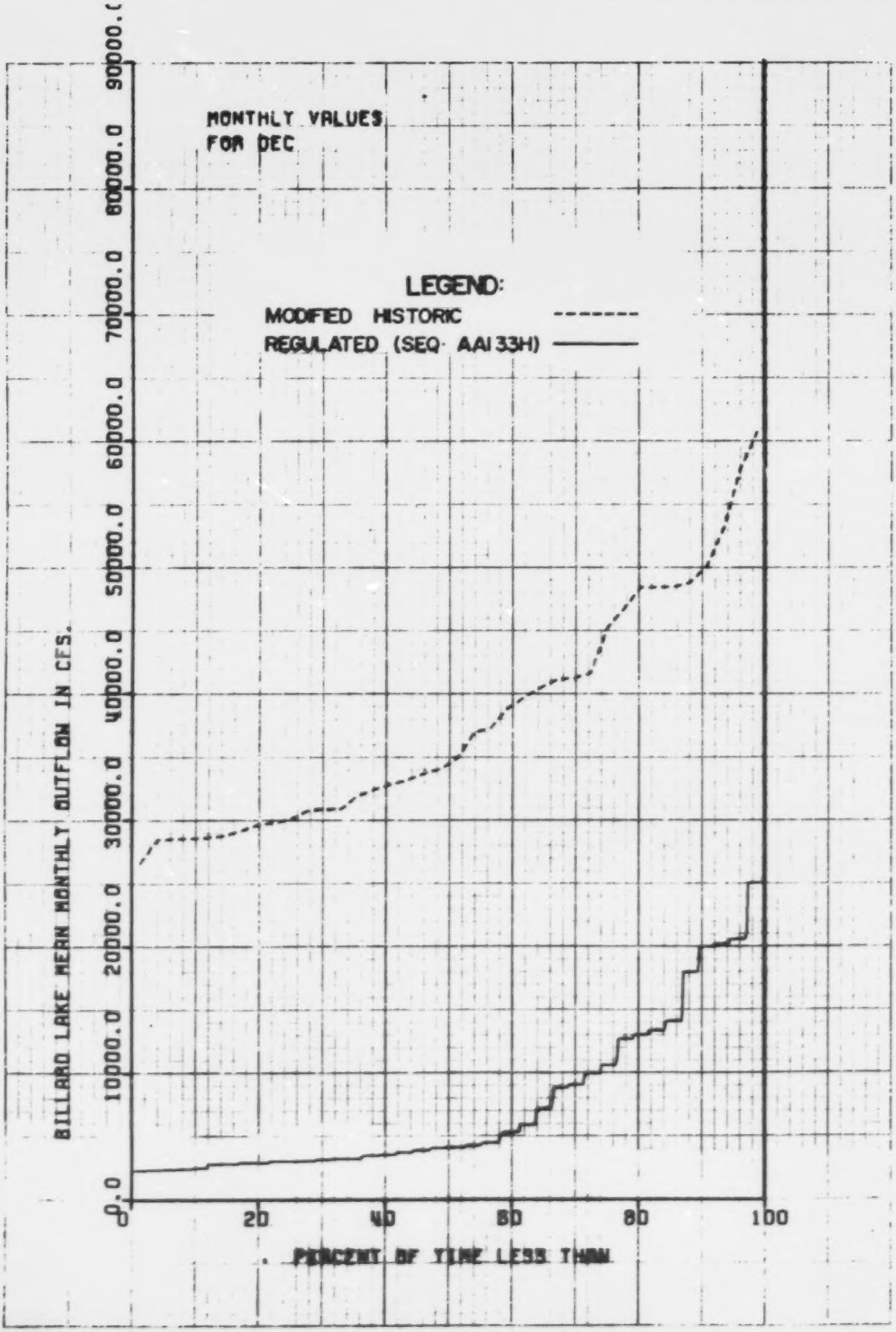

MONTHLY VALUES
FOR JUL
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40.
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR AUG
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR SEP
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE HERN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR OCT
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR NOV
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
BILLARD LAKE MEAN MONTHLY OUTFLOW IN CFS.
0.0
10000.0
20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
20
40
60
80
100
PERCENT OF TIME LESS THAN


MONTHLY VALUES
FOR DEC
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20000.0
30000.0
40000.0
50000.0
60000.0
70000.0
80000.0
90000.0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

SECTION 6

LOWER NELSON RIVER STUDY AREA

Nelson River
Flows
At The
Outlet of Split Lake

LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY

SPLIT LAKE OUTFLOWS HYDROLOGIC PERIOD 1927 - 1966

MODIFIED HISTORIC FLOWS

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	3	24	15	69	31	56	69	5	0	0	3	0	18	56	13	56	8	44	8	33	0	10	0	3
5-10	0	63	3	13	3	8	18	0	0	0	18	3	8	10	0	21	3	36	3	44	0	62	0	8
10-20	0	11	0	0	3	0	8	0	5	0	64	0	3	5	0	10	0	8	0	13	0	21	0	85
20-30	0	0	0	0	0	0	0	0	49	0	3	0	0	0	0	0	0	3	0	0	0	8	0	5
30-40	0	0	0	0	0	0	0	0	36	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
40-	0	0	0	0	0	0	0	0	10	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0

- FLOWS IN CFS -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	21472	22024	21938	25498	58429	69346	67219	61385	60051	50273	44628	26457	21472
AVERAGE	59390	57127	56729	60311	90201	105485	103719	99669	94941	90192	80704	66178	80387
MAXIMUM	100400	991260	87520	98520	132640	182210	184250	164520	141900	130930	116080	109700	184250

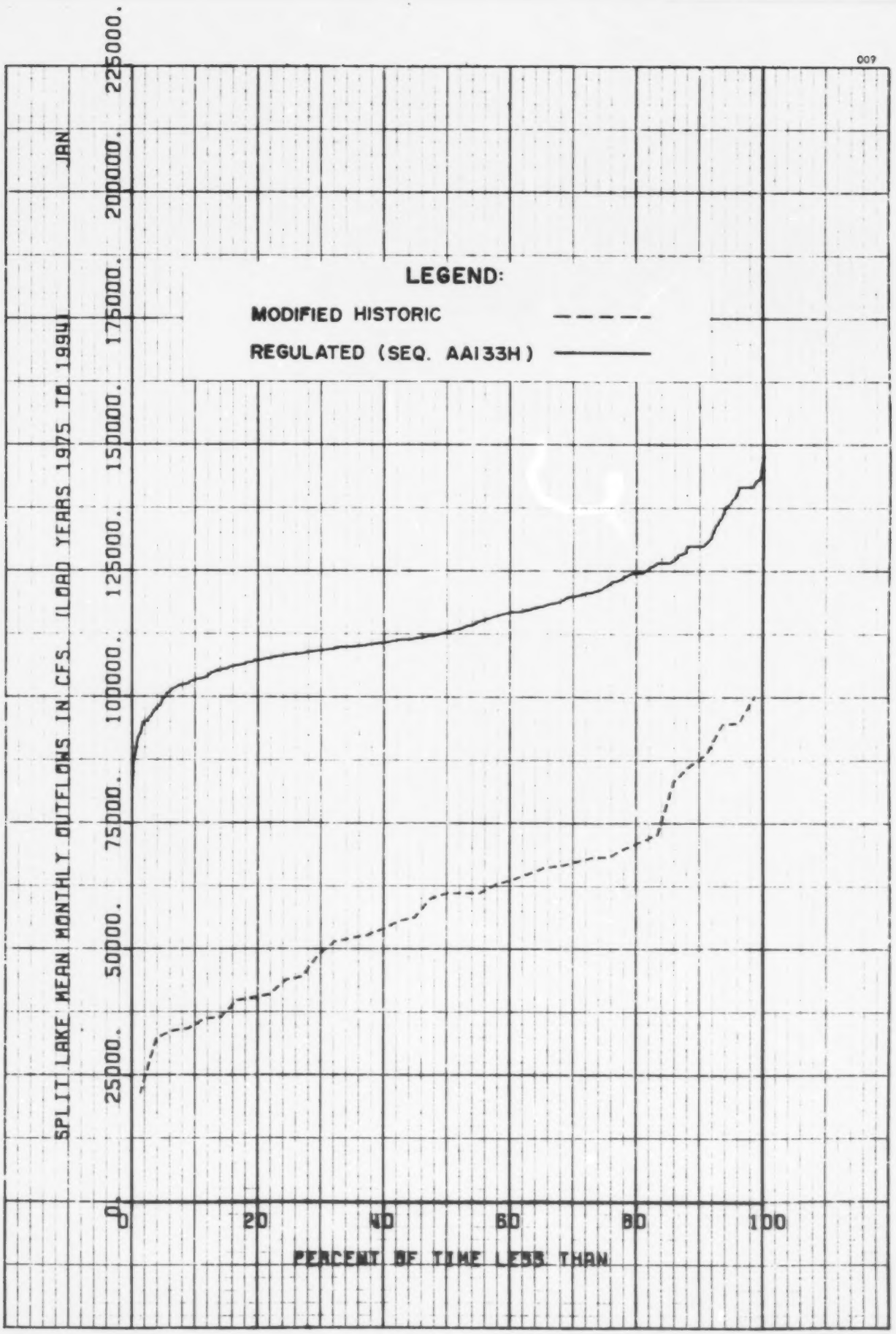
REGULATED CONDITION (SEQ. AA 133H)

- FLUCTUATIONS IN PERCENT -

Range 1000 CFS	January		February		March		April		May		June		July		August		September		October		November		December	
	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop	Rise	Drop
0-5	17	6	5	36	4	6	2	2	6	11	12	16	16	16	11	11	4	12	14	7	6	5	7	10
5-10	58	3	2	33	2	18	4	3	2	13	13	9	6	20	2	5	9	13	19	8	10	10	12	4
10-20	5	6	2	20	3	51	7	23	4	8	10	3	3	8	2	7	16	12	13	16	34	4	50	4
20-30	0	0	1	2	1	15	10	33	8	1	11	1	5	4	1	20	0	16	5	8	18	5	9	1
30-40	0	0	0	0	1	1	5	5	10	0	7	3	1	7	1	12	0	8	2	3	3	2	2	0
40-	3	1	0	0	0	0	2	2	37	0	16	1	7	5	1	28	0	10	2	2	2	0	1	0

- FLOWS IN CFS -

	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
MINIMUM	82598	73640	66470	52980	48450	54980	48900	50090	55830	60200	72610	85140	48450
AVERAGE	115512	109485	97951	90491	121144	136362	134220	108284	94937	93556	103074	112532	109796
MAXIMUM	147070	143760	132880	147040	217560	227040	223690	215230	147300	158920	134550	157230	227040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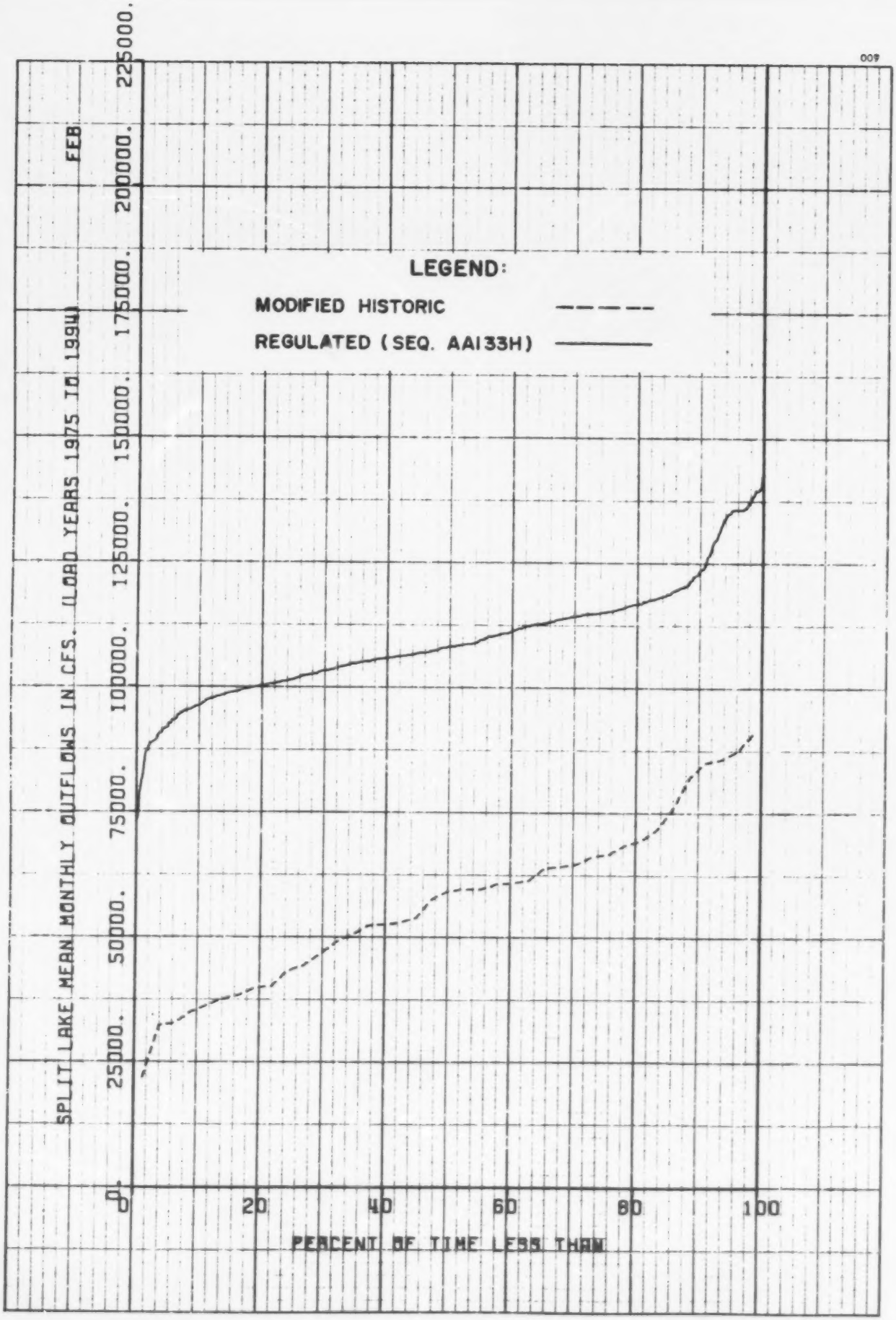
JAN
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
20
40
60
80
100
PERCENT OF TIME LESS THAN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LEGEND:
MODIFIED HISTORIC
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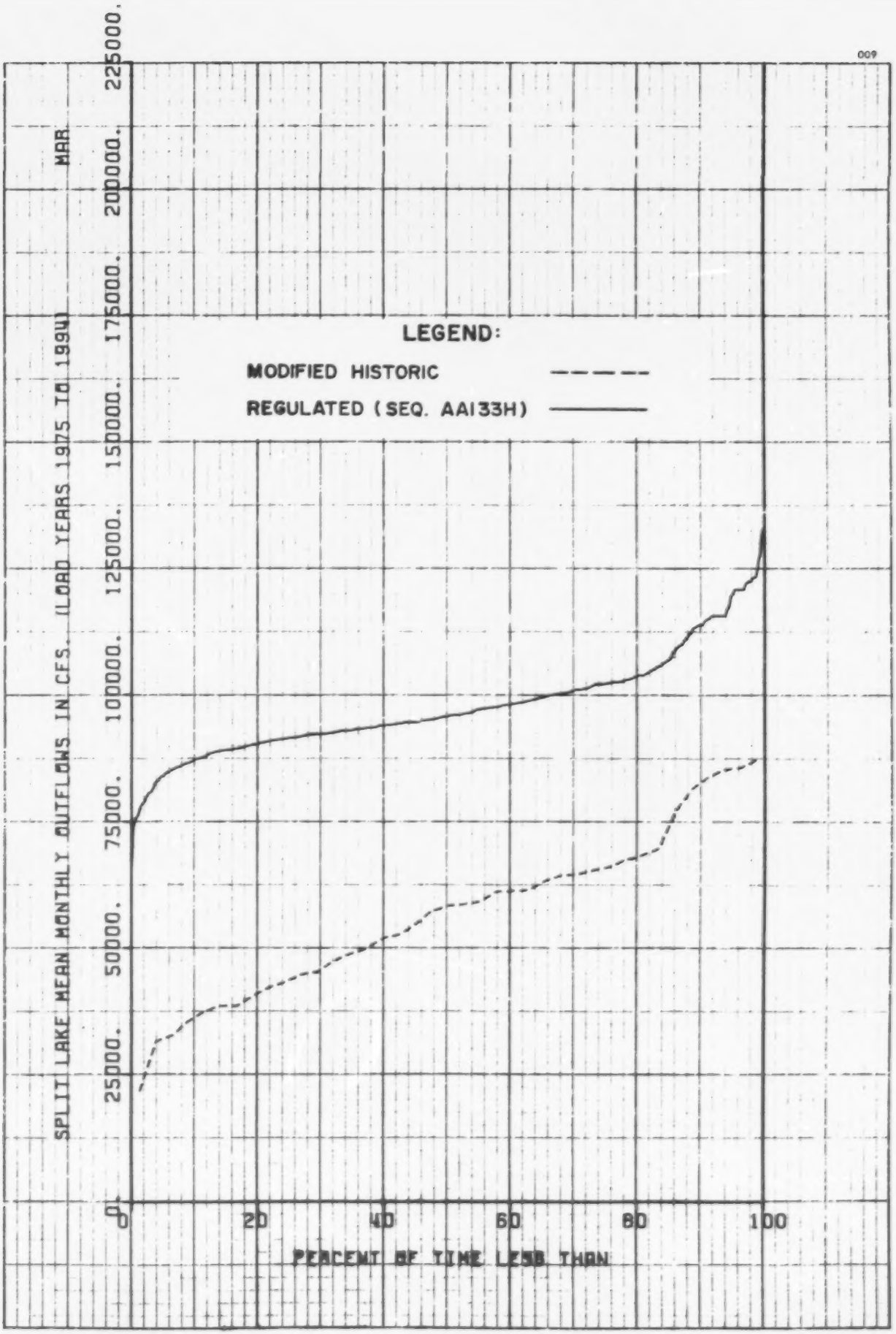
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
20
40
60
80
100
PERCENT OF TIME LESS THAN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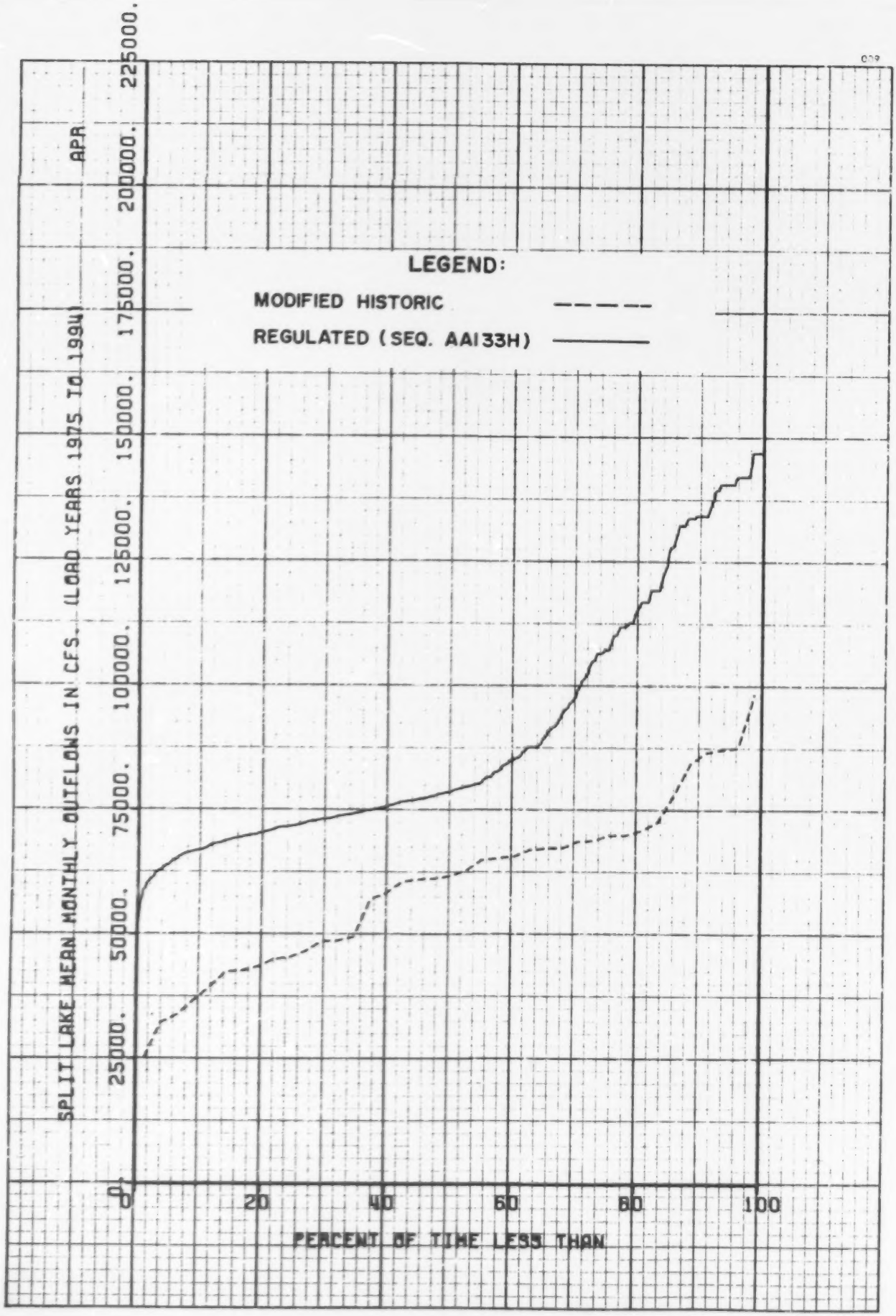
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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LEGEND:
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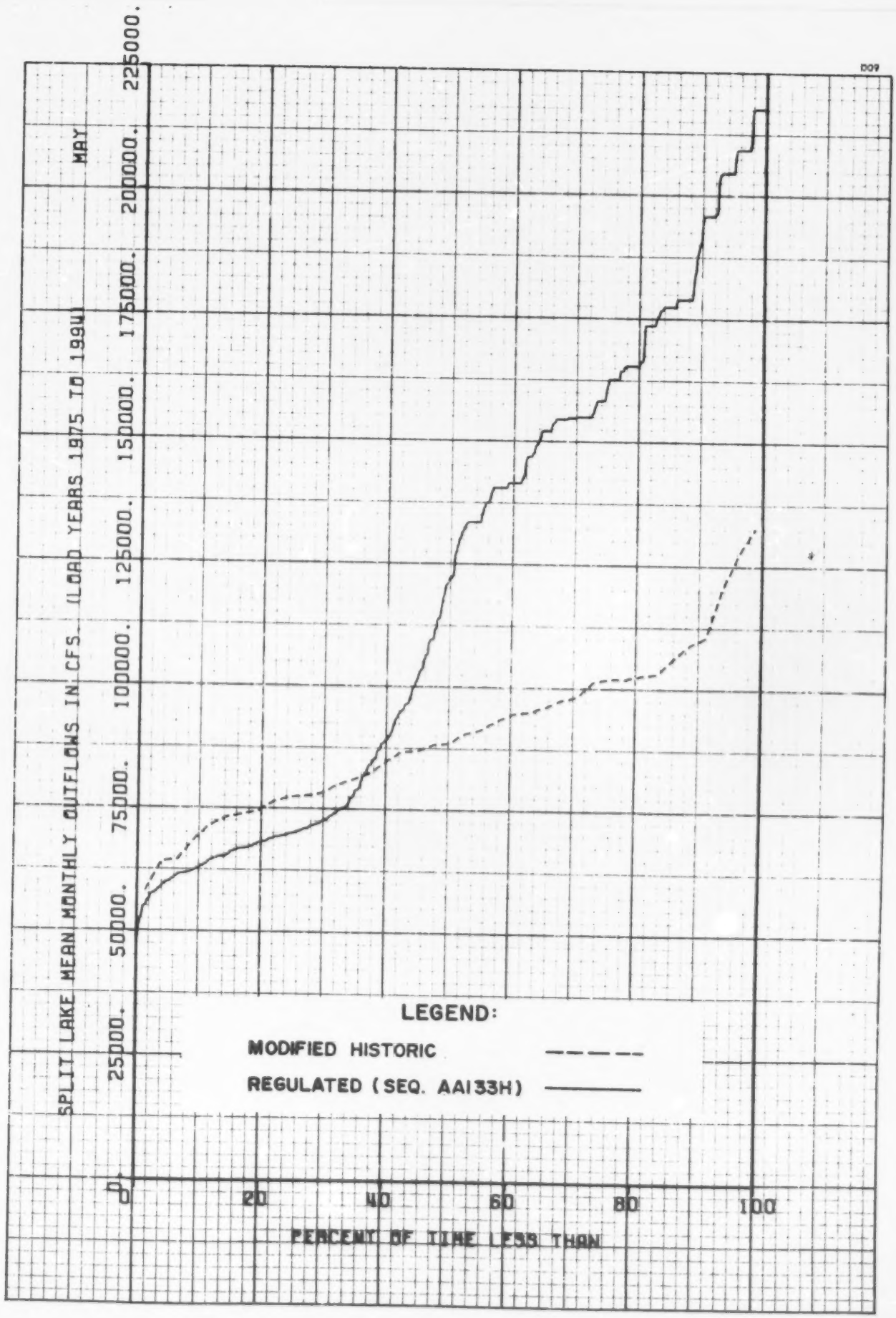
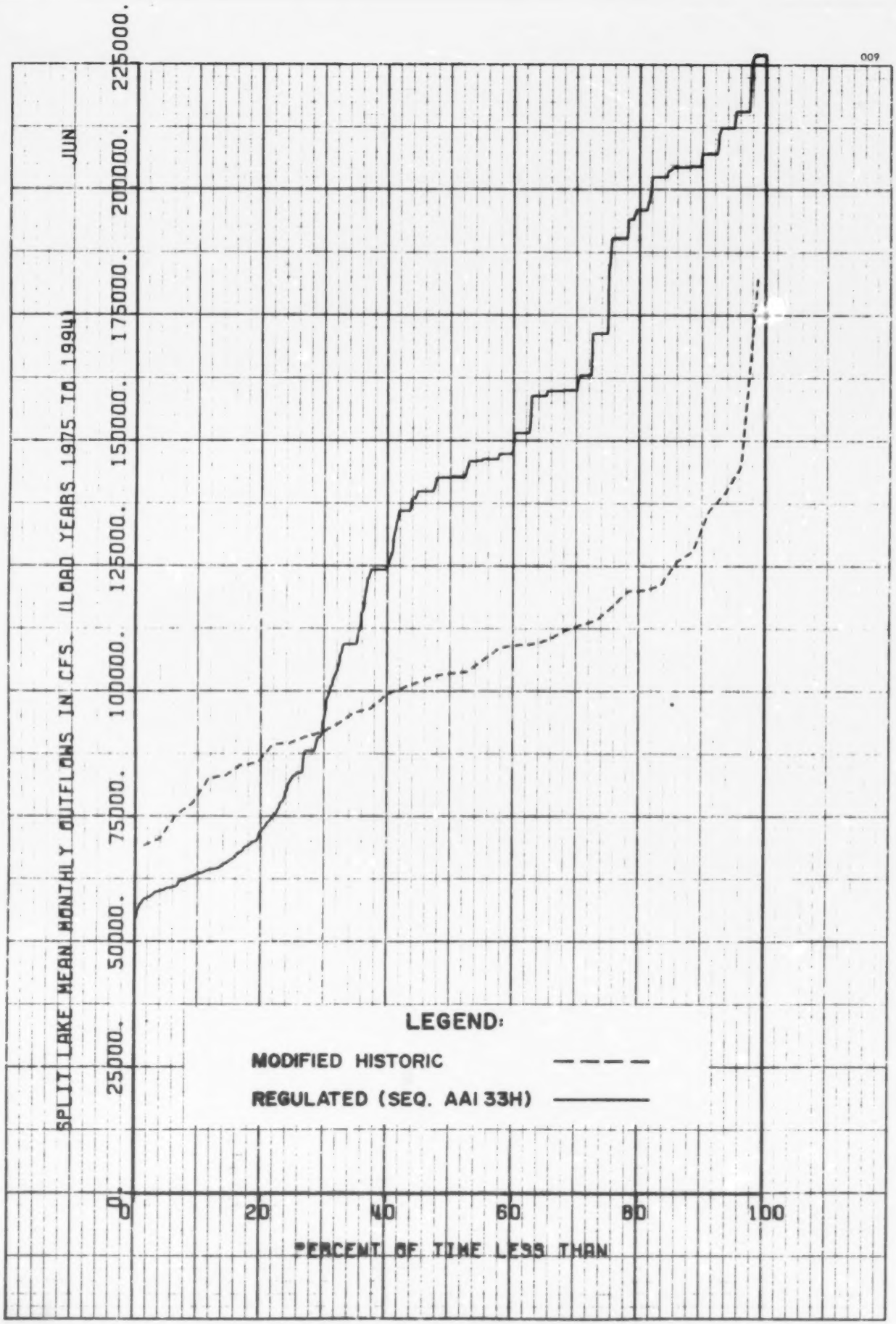
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN


009
SPLIT LAKE MEAN MONTHLY OUTFLOWS IN CFS. (LOAD YEARS 1975 TO 1994)
MAY
225000.
200000.
175000.
150000.
125000.
100000.
75000.
50000.
25000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)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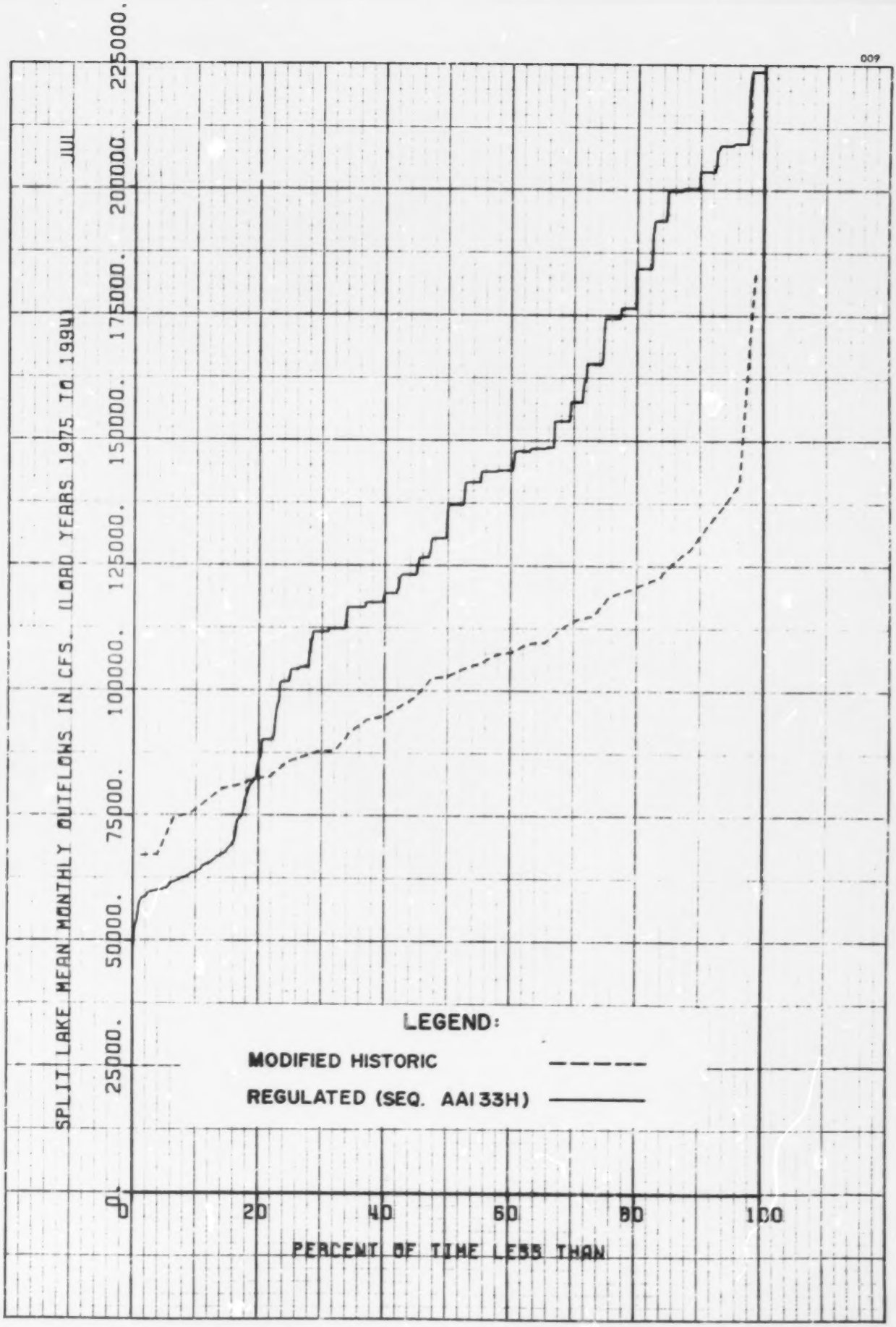
JUN
225000.
200000.
175000.
150000.
125000.
100000.
75000.
50000.
25000.
0.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)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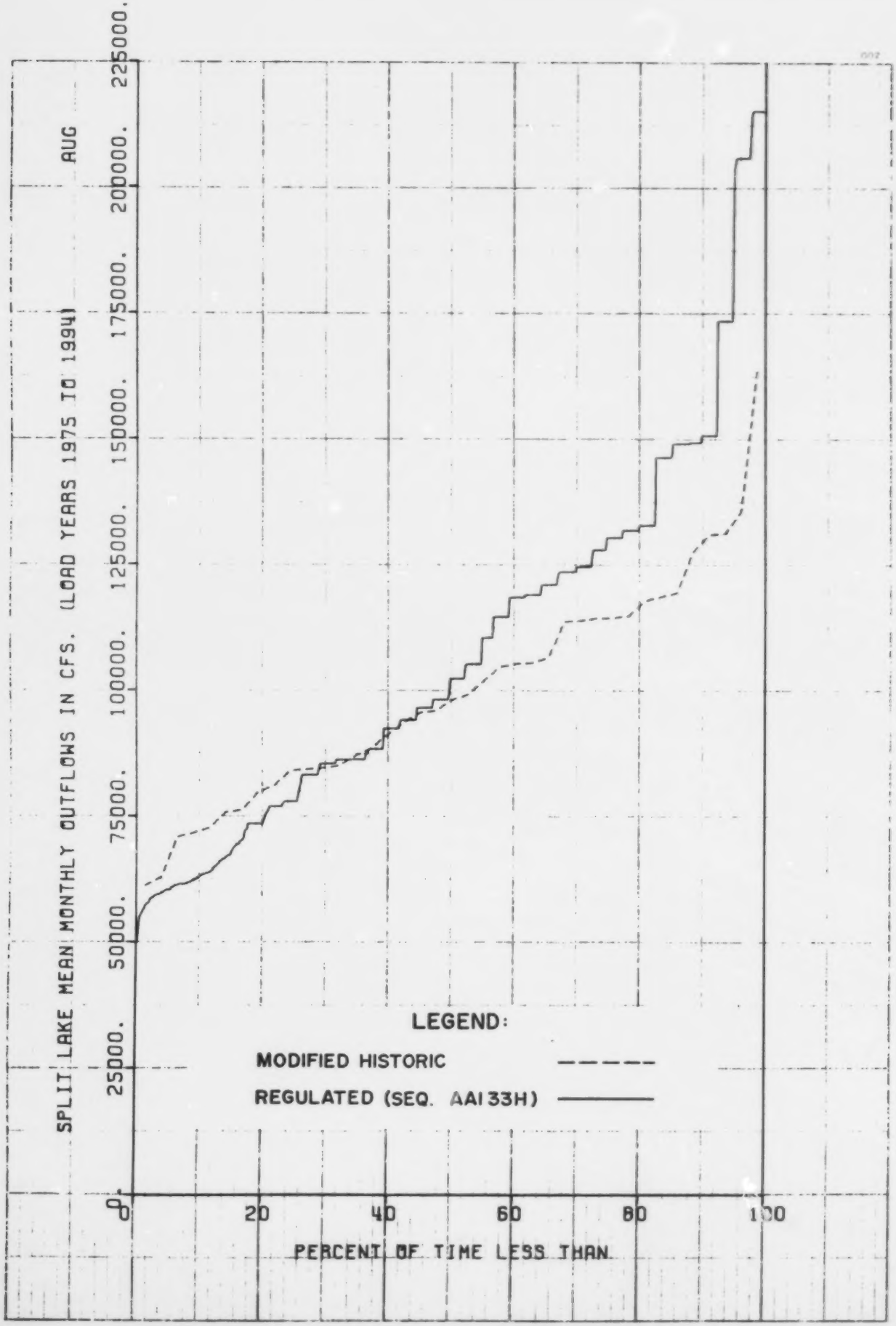
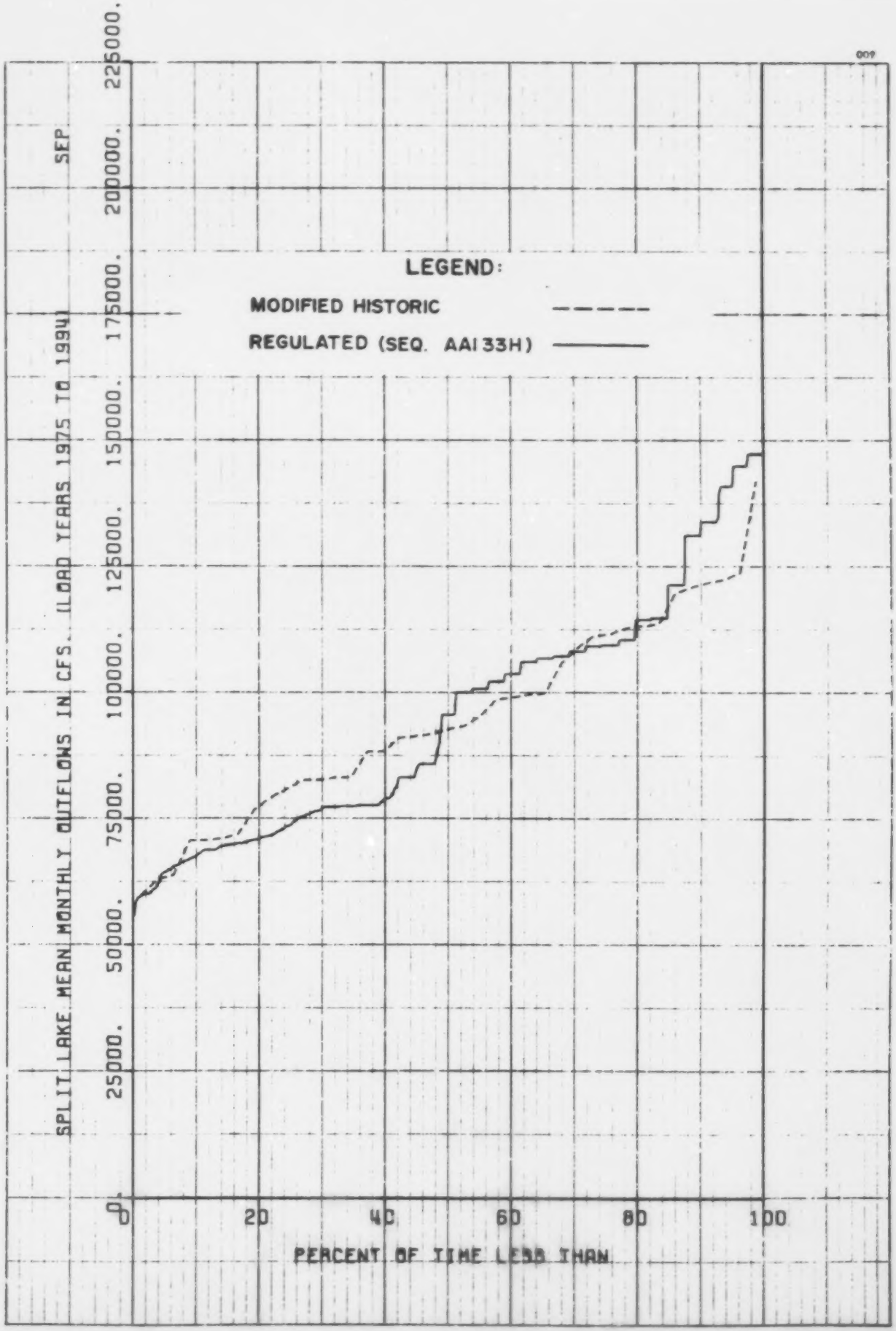
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)


SPLIT LAKE MEAN MONTHLY OUTFLOWS IN CFS. (LOAD YEARS 1975 TO 1994)
AUG
0.
25000.
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
0
20
40
60
80
100
PERCENT OF TIME LESS THAN
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AA133H)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100000.
125000.
150000.
175000.
200000.
225000.
LEGEND:
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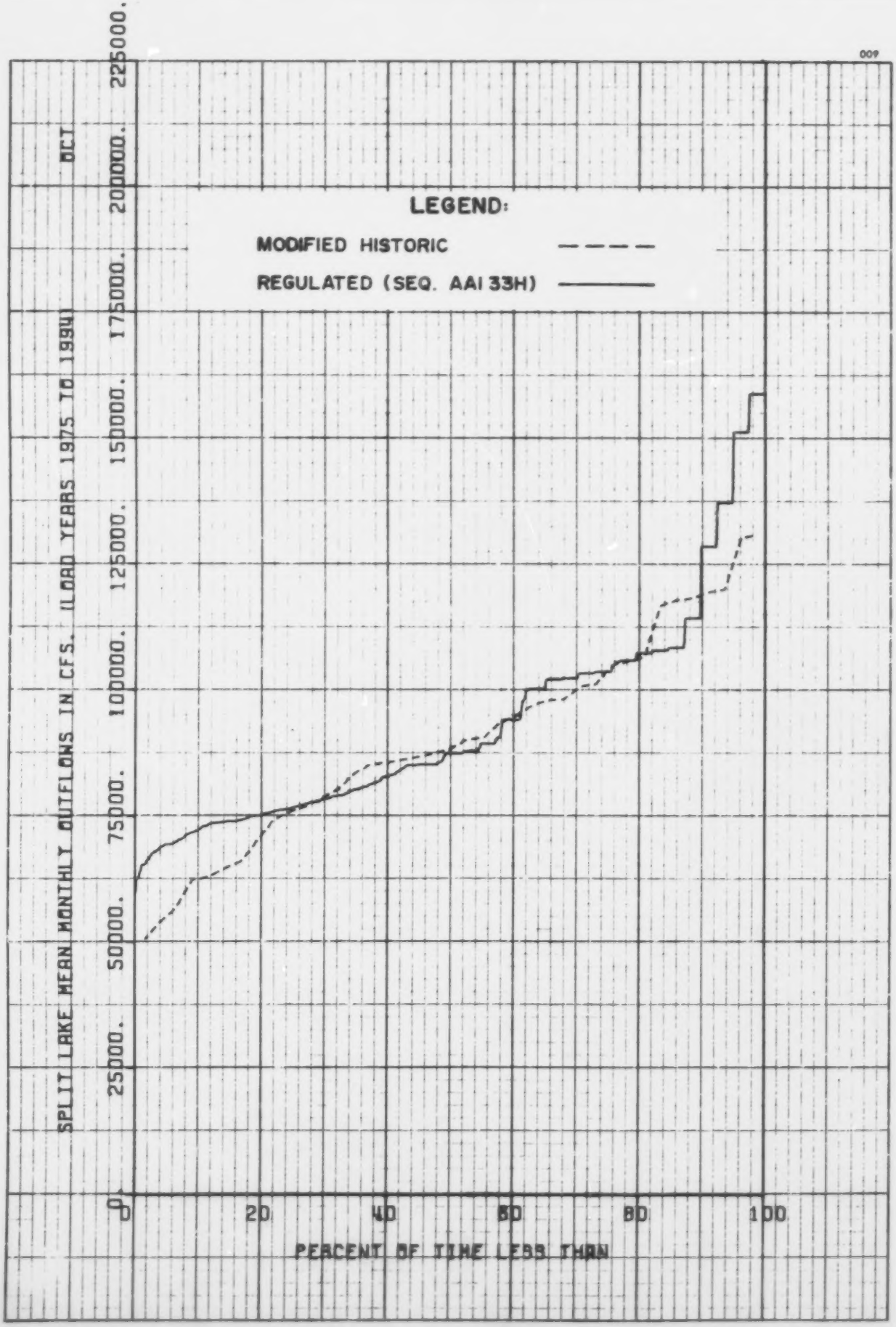
REGULATED (SEQ. AA133H)
0
20
40
60
80
100
PERCENT OF TIME LESS THAN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OCT
0.
25000.
50000.
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225000.
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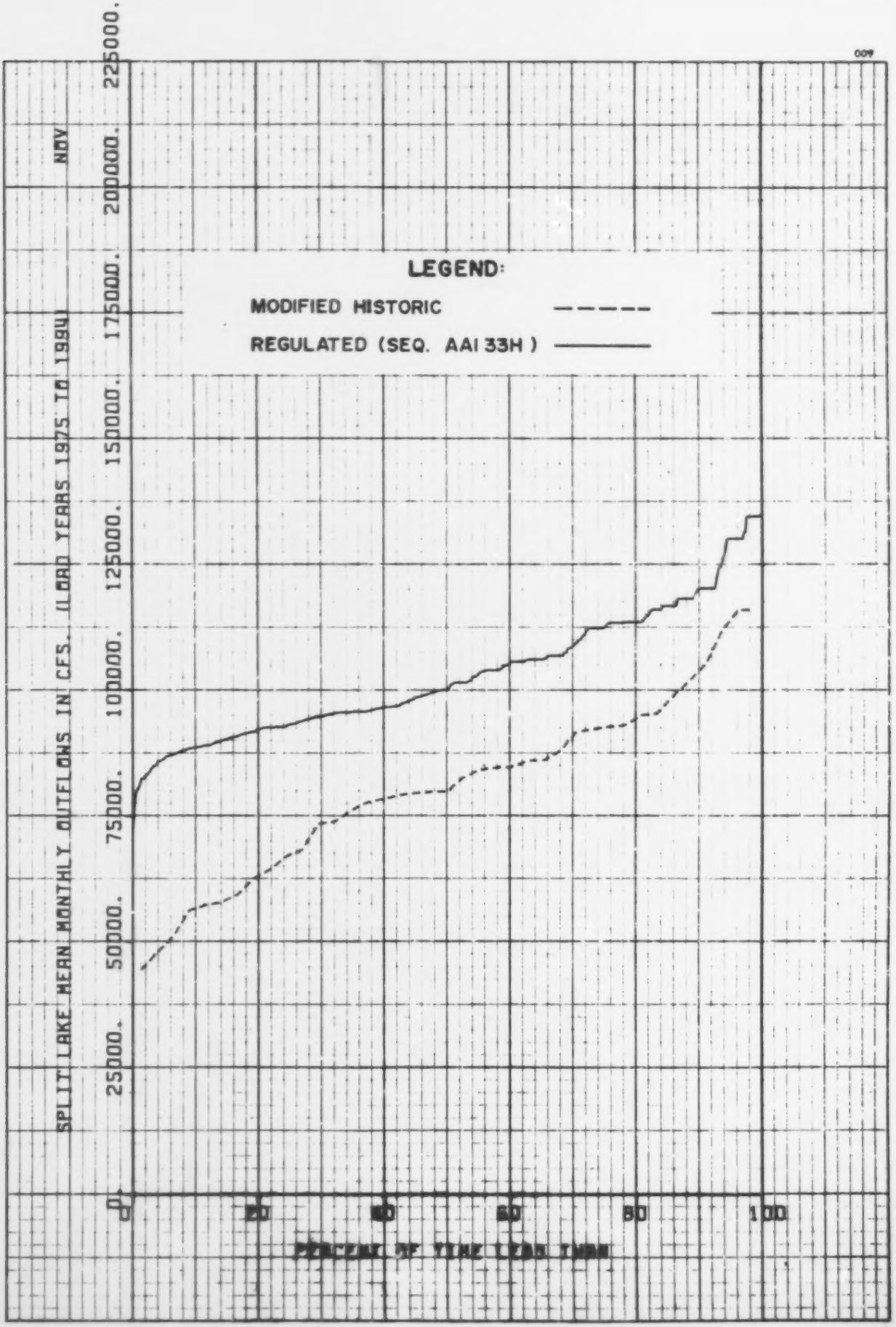
40
60
80
100
PERCENT OF TIME LESS THAN


NOV
SPLIT LAKE MEAN MONTHLY OUTFLOWS IN CFS. (LOAD YEARS 1975 TO 1994)
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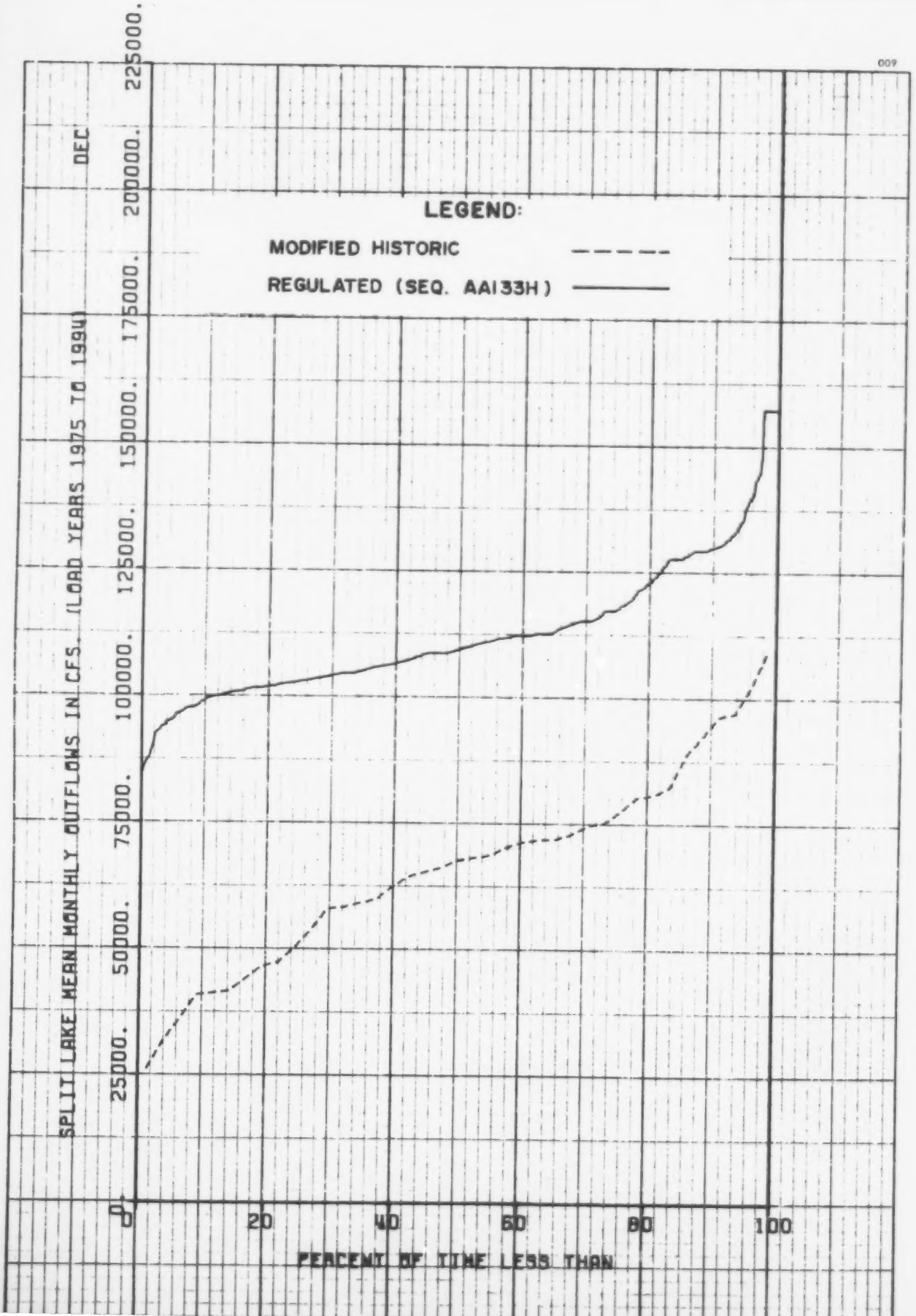
50000.
75000.
100000.
125000.
150000.
175000.
200000.
225000.
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI 33H)
20
40
60
80
100
PERCENT OF TIME LESS THAN


009
LEGEND:
MODIFIED HISTORIC
REGULATED (SEQ. AAI33H)
SPLIT LAKE MEAN MONTHLY OUTFLOWS IN CFS. (LOAD YEARS 1975 TO 1994)
DEC
225000.
200000.
175000.
150000.
125000.
100000.
75000.
50000.
25000.
0
0
20
40
60
80
100
PERCENT OF TIME LESS THAN

APPENDIX 2. VOL. 2 - C
LAKE WINNIPEG SOUTH BASIN
MAPPING PROJECT

LAKE WINNIPEG SOUTH BASIN
MAPPING PROJECT

by

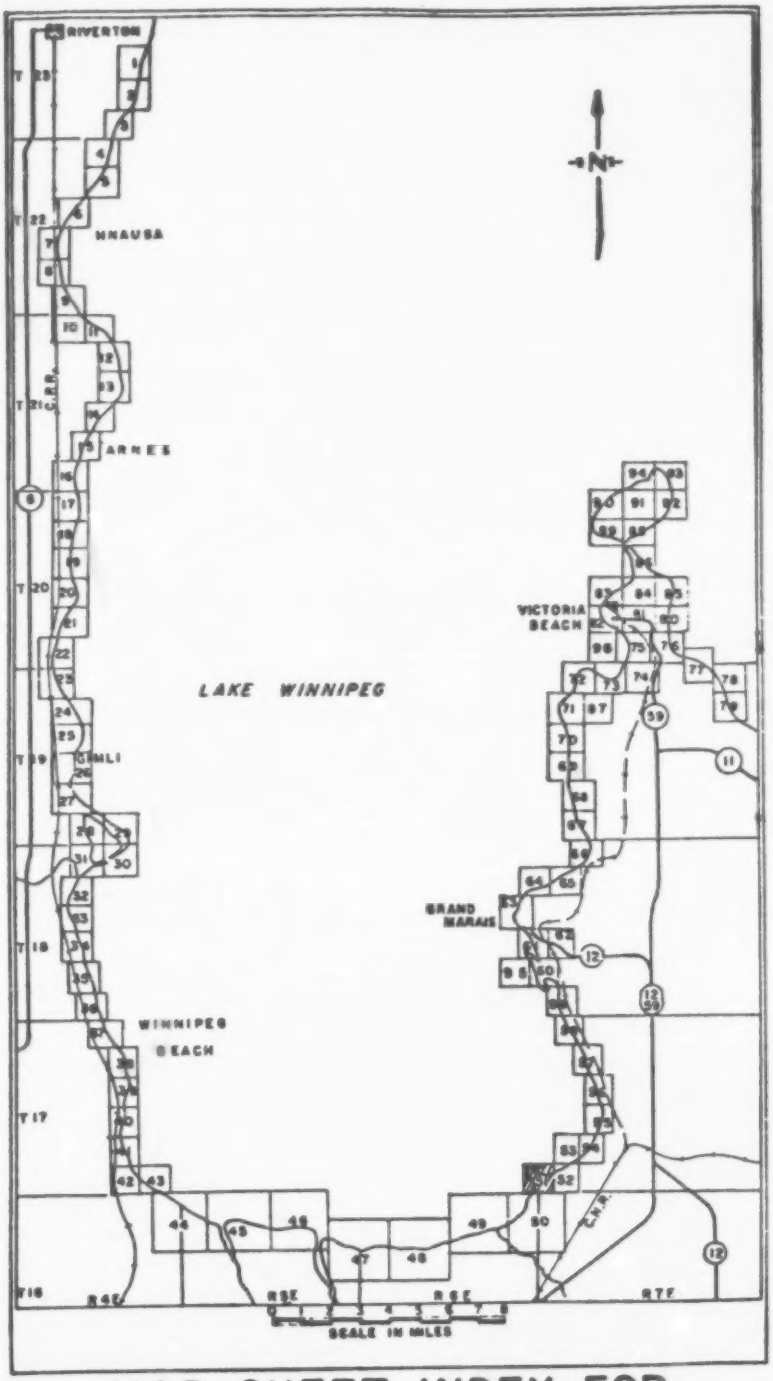
Lockwood Survey Corporation Limited
Winnipeg, Manitoba
March, 1972

sub-contracted by:

Surveys and Mapping Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD



MAP SHEET INDEX FOR LAKE WINNIPEG SHORELINE AND SHORE TOPOGRAPHY MAPPING

Fig. 1. Lake Winnipeg South Basin Mapping Project

Topographic maps of the south basin of Lake Winnipeg between Riverton and Traverse Bay (Fig. 1) have been prepared for the Lake Winnipeg, Churchill and Nelson Rivers Study Board. The mapping extends from the shoreline to 3000 ft inland at a horizontal scale of 1:2400 with a contour interval of 2 ft. Roads and buildings near the shoreline and the location of the shoreline at several different points in time. Copies of these maps are available from the Map Sales Office, Manitoba Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba.

APPENDIX 2, VOL. 2 - D
RAT-BURNTWOOD RIVERS SYSTEM
MAPPING PROJECT

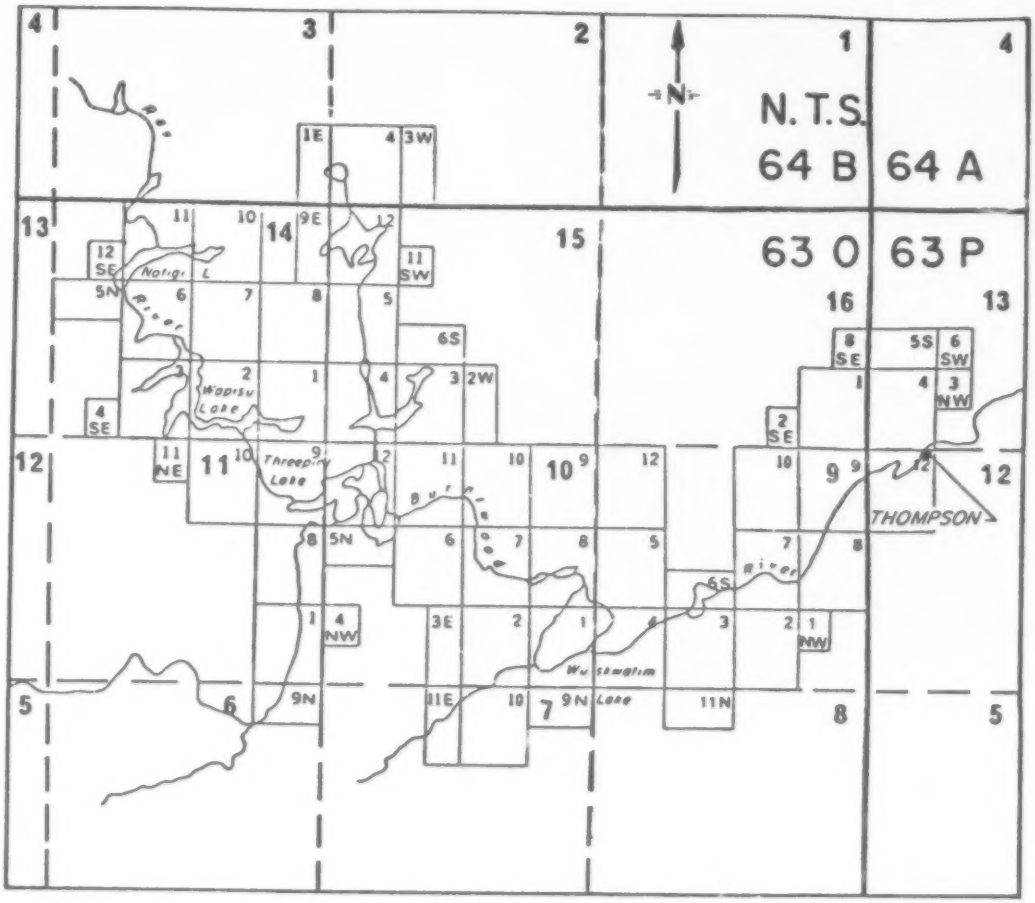
RAT-BURNTWOOD RIVERS SYSTEM
MAPPING PROJECT

by

Surveys and Mapping Branch
Manitoba Department of Mines, Resources and Environmental Management
Winnipeg, Manitoba
July, 1973

for

THE LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD



MAP SHEET INDEX FOR BURNTWOOD RIVER MAPPING PROJECT

Fig. 1. Rat-Burntwood Rivers System Mapping Project

The Lake Winnipeg, Churchill and Nelson Rivers Study Board funded the mapping of the Rat-Burntwood rivers between the 21st base line north of Notigi Lake and Manasan Falls (Fig. 1). This area was mapped at a horizontal scale of 1;12,000, with a contour interval of 10 ft, using a rectified photographic mosaic as a base. Copies of these maps are available from the Map Sales Office, Manitoba Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba.